Coldwater River Watershed Hydrologic Study

Michigan's Nonpoint Source Program

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DEQ
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Summary

A hydrologic model of the Coldwater River watershed was developed by the Hydrologic Studies Unit (HSU) of the Michigan Department of Environmental Quality (MDEQ) using the Hydrologic Engineering Center's Hydrologic Modeling System (HEC-HMS). The hydrologic model was developed in conjunction with the watershed management plan to help determine the effect of drainage system alterations and land use changes on the Coldwater River's flow regime and to provide design flows for streambank stabilization Best Management Practices (BMPs). The Coldwater River Watershed Council may combine this information with other determinants, such as open space preservation, to decide what locations are the most appropriate for wetland restoration, stormwater detention, in-stream BMPs, or upland BMPs. The communities within the watershed could also use the information to help develop stormwater ordinances.

The hydrologic model has three scenarios corresponding to land uses in 1800 and 1978 land use. General land use trends, illustrated in Figure 1, show that the watershed has transitioned to primarily agricultural uses, with a net loss of natural areas. More detailed land use information is provided in the Watershed Description and Model Parameters section of this report.

Because of these land use trends, the model shows increases in runoff volumes and peak flows from 1800 to 1978 for both the 50 percent chance (2-year) and 4 percent chance (25-year) design storms, as shown in Figures 7 through 10. Additional flow details are in the Model Results section of this report. Increases in the runoff volume and peak flow from the 4 percent chance, 24-hour storms could cause or aggravate flooding problems unless mitigated through the use of effective stormwater management techniques. Increases in the 50 percent chance, 24-hour storm will increase channel-forming flows. The channel-forming flow in a stable stream usually has a one- to two-year recurrence interval. These relatively modest storm flows, because of their higher frequency, have more effect on channel form than extreme flood flows.

Hydrologic changes that increase this flow can cause the stream channel to become unstable. Stream instability is indicated by excessive erosion at many locations throughout a stream reach. Stormwater management techniques used to mitigate flooding can also help mitigate projected channel-forming flow increases. However, channel-forming flow criteria should be specifically considered in the stormwater management plan so that the selected BMPs will be most effective. For example, detention ponds designed to control runoff from the 4 percent chance, 24-hour storm often do little to control the runoff from the 50 percent chance, 24-hour storm, unless the outlet is specifically designed to do so.

One way to compare runoff from different subbasins is to calculate the yield, which is the peak flow divided by the drainage area. The average yield from the 50 percent chance (2-year), 24-hour storm for the Coldwater River watershed is 0.02 cubic feet per second per acre (cfs/acre) for 1978 land use conditions. This value has implications for fish habitat and stream stability management. The average yield from the 4 percent

chance (25-year), 24-hour storm for the Coldwater River watershed is 0.08 cfs/acre for 1978 land use conditions. This value has implications for flood control management. Additional details are shown in Figures 11 through 13 and in the Model Results section of this report. Based on these results, the developers of the watershed plan may want to consider whether the Kent County model ordinance standards will adequately protect the Coldwater River and its tributaries.

Some stakeholders have speculated that the Coldwater River has become flashier because the upper watershed's drainage system, particularly in Ionia County, has become more efficient due to the installation and channelization of drains. The model can simulate this by increasing the time of concentration parameters. In the Modified Drainage scenario, the times of concentration for the thirteen subbasins contributing to Bear Creek, Duck Creek, and Pratt Lake Creek were increased by 20 percent to simulate a less efficient drainage system. All other parameters are identical to the 1978 scenario. The results are shown in Figures 14 and 15 for the 50 percent chance and 4 percent chance storms, respectively. The changes had little effect on computed peak flows. If excessive streambank erosion or increasing flooding are identified as problems in the Coldwater River watershed plan, the primary causes appear to be the changes in land use and loss of storage, not the installation and channelization of drains.

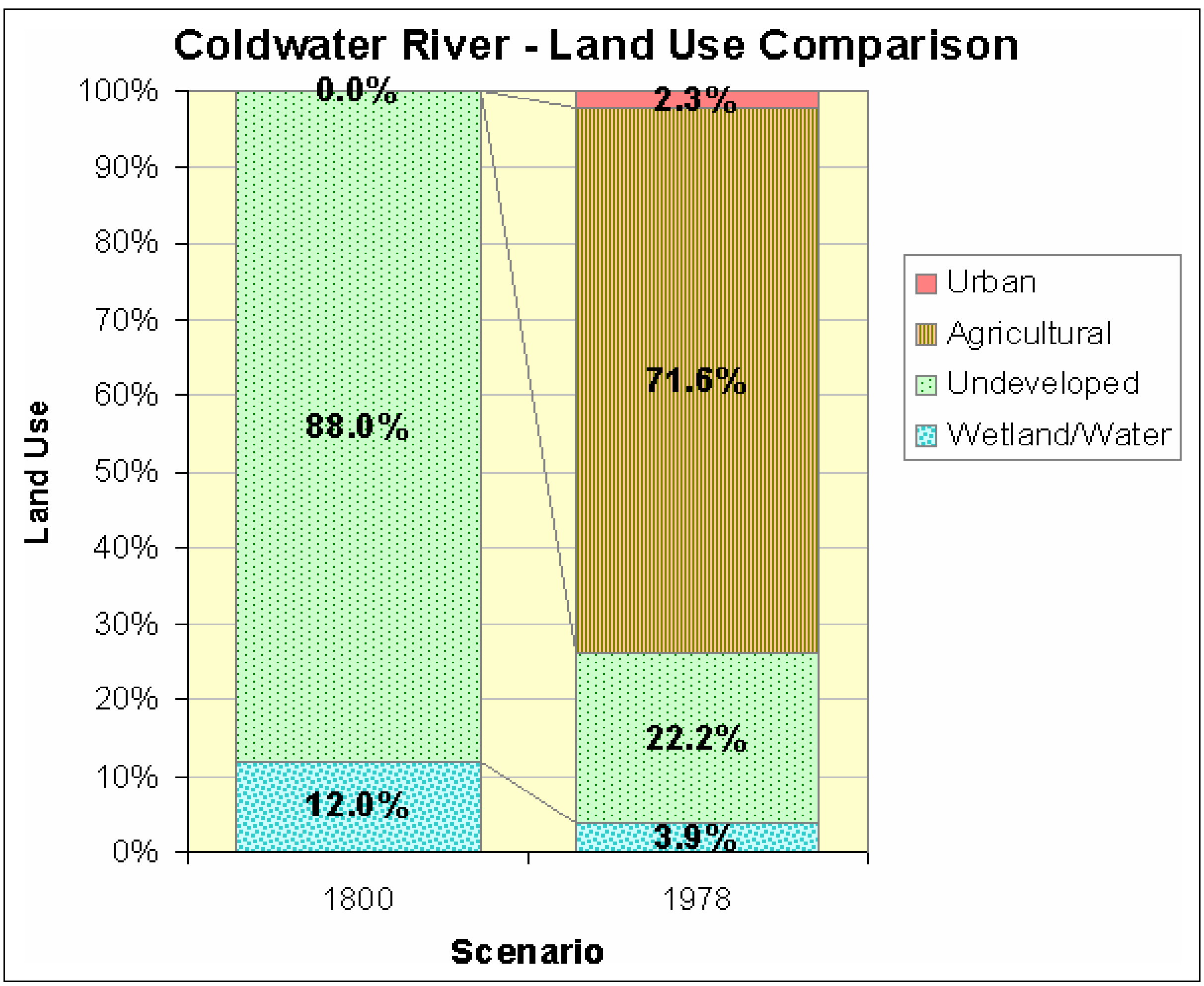


Figure 1: Land Use Comparison

Project Goals

The Coldwater River hydrologic study was initiated in support of a Lower Grand River watershed project, which is funded in part by a United States Environmental Protection Agency (USEPA) Part 319 grant administered by the MDEQ. The goals of this study are:

- To better understand the watershed's hydrologic characteristics and the impact of hydrologic changes in the Coldwater River watershed
- To facilitate the selection and design of suitable BMPs
- To provide information that can be used by local units of government to develop or improve stormwater ordinances

Watershed Description and Model Parameters

The 187 square mile Coldwater River watershed, Figure 2, outlets to the Thornapple River and is located in Barry, Kent, Ionia, and Eaton counties. This Coldwater River study divides the watershed into 31 subbasins, as shown in Figure 3. Some areas have been identified as non-contributing, meaning that they do not have an apparent overland outlet for surface runoff. We have assumed that these areas do not contribute surface runoff to the Coldwater River or its tributaries and are not included in the hydrologic model.

Our analysis of the watershed uses the curve number technique to calculate surface runoff volumes and peak flows. This technique, developed by the Natural Resources Conservation Service (NRCS) in 1954, represents the runoff characteristics from the combination of land use and soil data as a runoff curve number. The curve numbers for each subbasin, listed in Appendix A, were calculated from digital soil and land use data using Geographic Information Systems (GIS) technology.

Runoff curve numbers were calculated from the land use and soil data shown in Figures 4 through 6. Land use maps based on the MDEQ GIS data for 1800 and 1978 are shown in Figures 4 and 5, respectively. The 1800 land use information is provided at the request of the Coldwater River project manager. The MDEQ Nonpoint Source program does not expect or recommend that the flow regime calculated from 1800 land use be used as criteria for BMP design or as a goal for watershed managers.

The NRCS soils data for the watershed is shown in Figure 6. Where the soil is given a dual classification, B/D for example, the soil type was selected based on land use. In these cases, the soil type is specified as D for natural land uses or the alternate classification (A, B, or C) for developed land uses. The runoff curve numbers calculated from the soil and land use data are listed in Appendix A. The percent impervious field is left at 0.0, because it is already incorporated in the curve numbers. The initial loss field is left blank so that HMS uses the default equation based on the curve number.

The time of concentration for each subbasin, which is the time it takes for water to travel from the hydraulically most distant point in the watershed to the design point, was calculated from the USGS quadrangles. The storage coefficients, which represent storage in the subbasin, were iteratively adjusted to provide a peak flow reduction equal to the ponding adjustment factors described further in Appendix A.

The reach routing method is the lag method, with one exception. Lag is the travel time of water within each section of the stream. The method translates the flood hydrograph through the reach without attenuation. It is not appropriate for reaches that have ponds, lakes, wetlands, or flow restrictions that provide storage and attenuation of floodwater. The Coldwater River between Andrews and Farrrel Roads has a 274-acre wetland complex along the river, according to USGS quadrangles. That reach is modeled using the Modified Puls routing method to account for the storage. Lag and Modified Puls values for each reach are calculated using USGS quadrangles and are listed in Appendix A.

The selected precipitation events were the 50 and 4 percent chance (2- and 25-year), 24-hour storms. Design rainfall values for these events are tabulated in *Rainfall Frequency Atlas of the Midwest*, Bulletin 71, Midwestern Climate Center, 1992, pp. 126-129, and summarized for this site in Appendix A. These values have been multiplied by 0.92 to account for the size of the watershed.

These parameters were then incorporated into a HEC-HMS model to compute runoff volume and flow. Precipitation and flow monitoring data, Appendix C, were collected to calibrate the hydrologic model. Model calibration is further discussed in Appendix B.

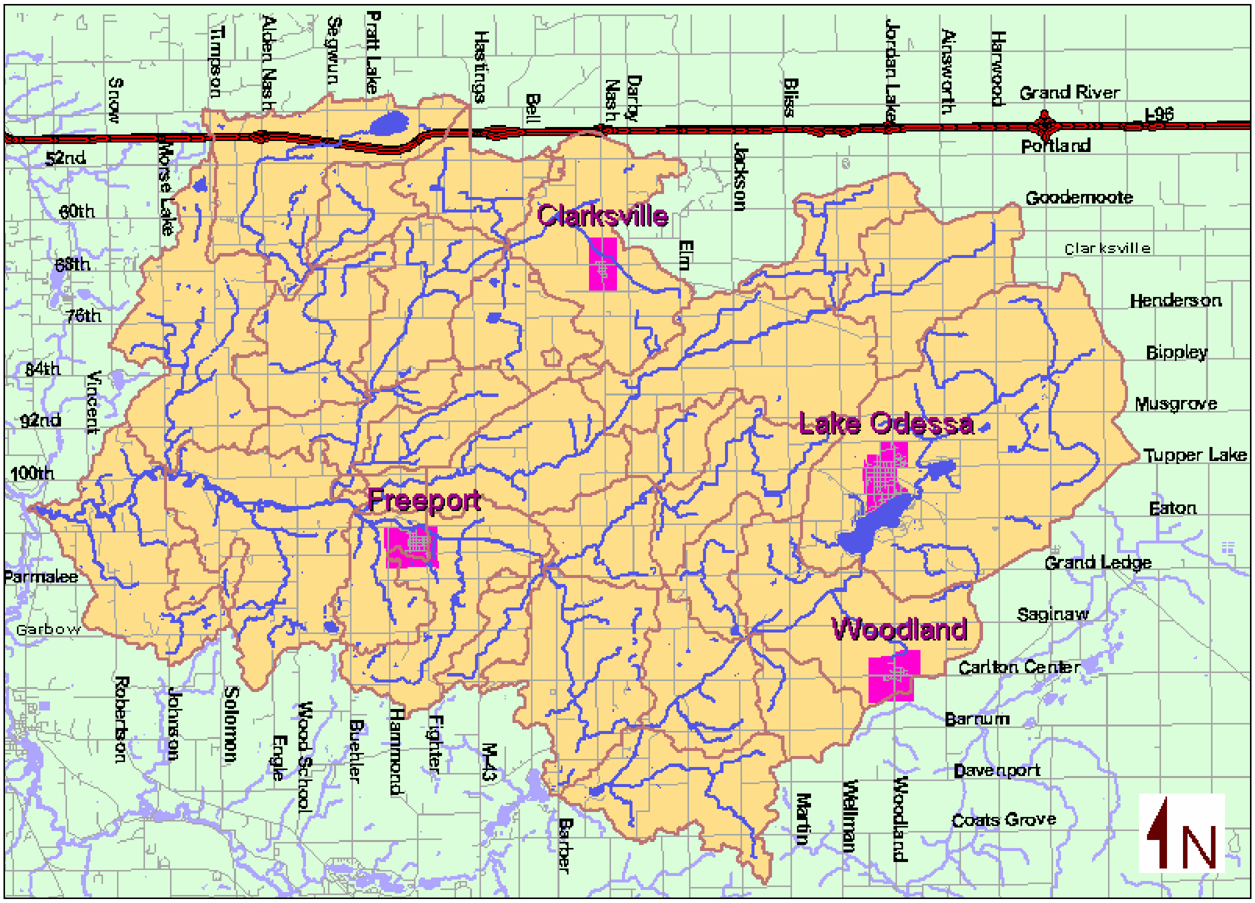
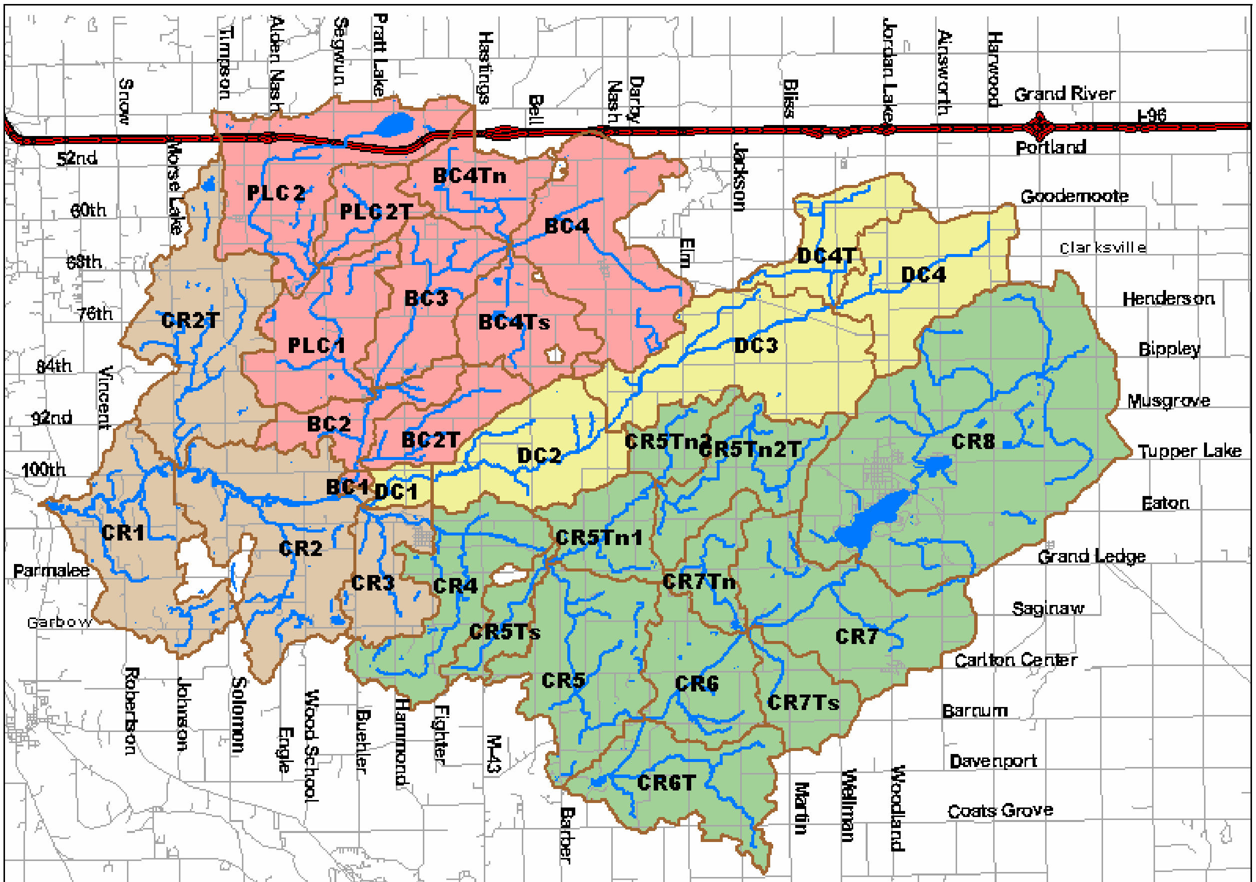


Figure 2: Delineated Coldwater River Watershed



Bear Creek
BC1: Bear Creek, at mouth
BC2: Bear Creek, at 100th Street
BC2T: Walton Drain
BC3: Bear Creek, near Pratt Lake Creek
BC4: Bear Creek, at confluence with two drains
BC4Tn: Unnamed tributary to Bear Creek
BC4Ts: Peddler Lake Drain
PLC1: Pratt Lake Creek, at mouth
PLC2: Pratt Lake Creek, at Kilgus Branch
PLC2T: Kilgus Branch

Lower Coldwater River
CR1: Coldwater River, at mouth
CR2: Coldwater River, at Morse Lake Road
CR2T: Clark and Bunker Drain
CR3: Coldwater River, at Duck Creek

Upper Coldwater River
CR4: Coldwater River, at Montcalm Road
CR5: Coldwater River, at Messer Brook
CR5Tn1: Messer Brook, at mouth
CR5Tn2: Messer Brook, at Kart Creek
CR5Tn2T: Kart Creek, at mouth
CR5Ts: Bird Drain
CR6: Coldwater River, at Lower Lake tributary
CR6T: Lower Lake tributary
CR7: Little Thornapple River, at unnamed tributary
CR7Tn: Mallson Drain
CR7Ts: Unnamed tributary to Coldwater River
CR8: Little Thornapple River, at Jordan Lake Dam

Duck Creek
DC1: Duck Creek, at mouth
DC2: Duck Creek, at Montcalm Road
DC3: Duck Creek, at Nash Highway
DC4: Duck Creek, at unnamed tributary
DC4T: Unnamed tributary to Duck Creek

Figure 3: Subbasin Identification

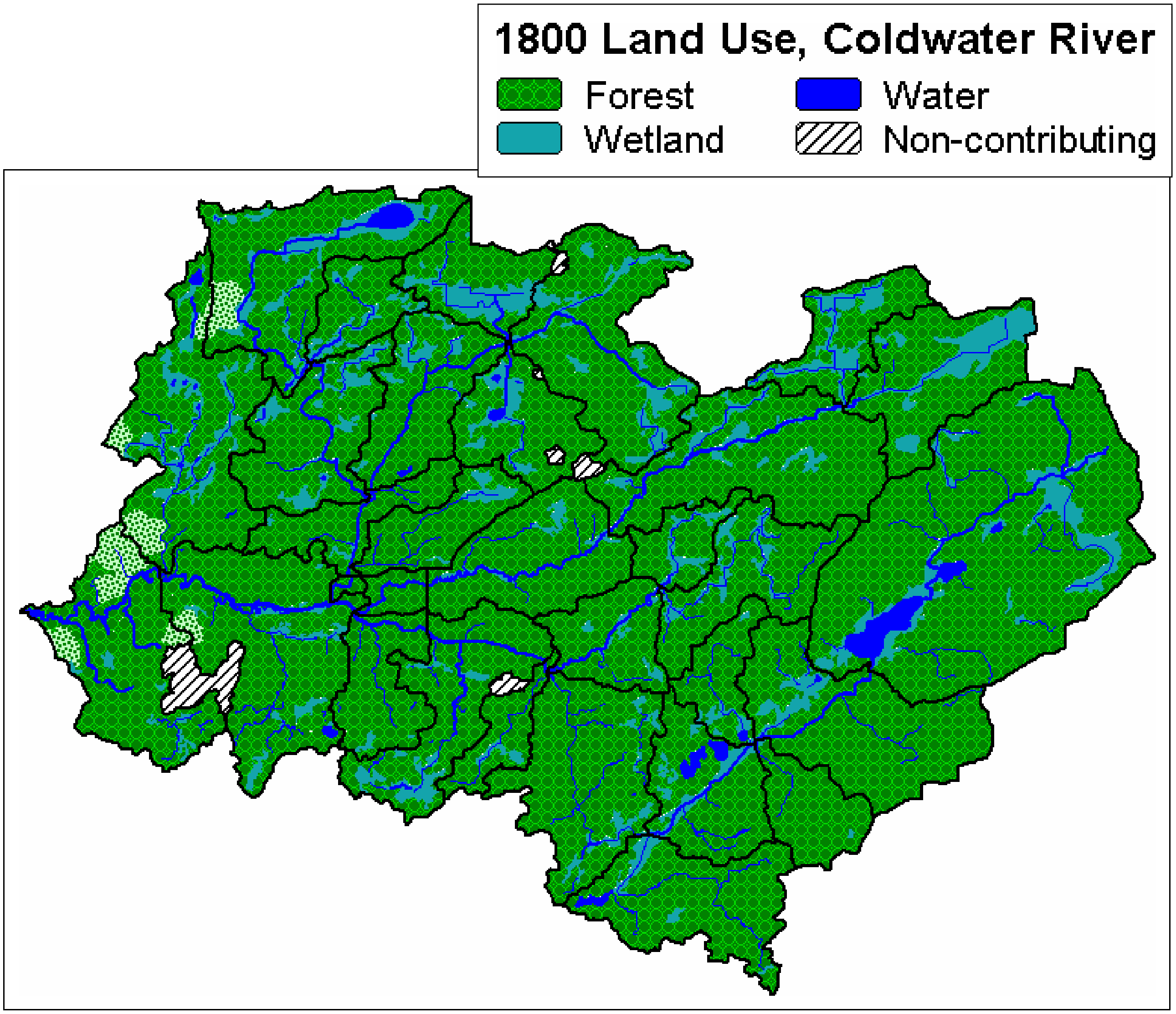


Figure 4: 1800 Land Use Data

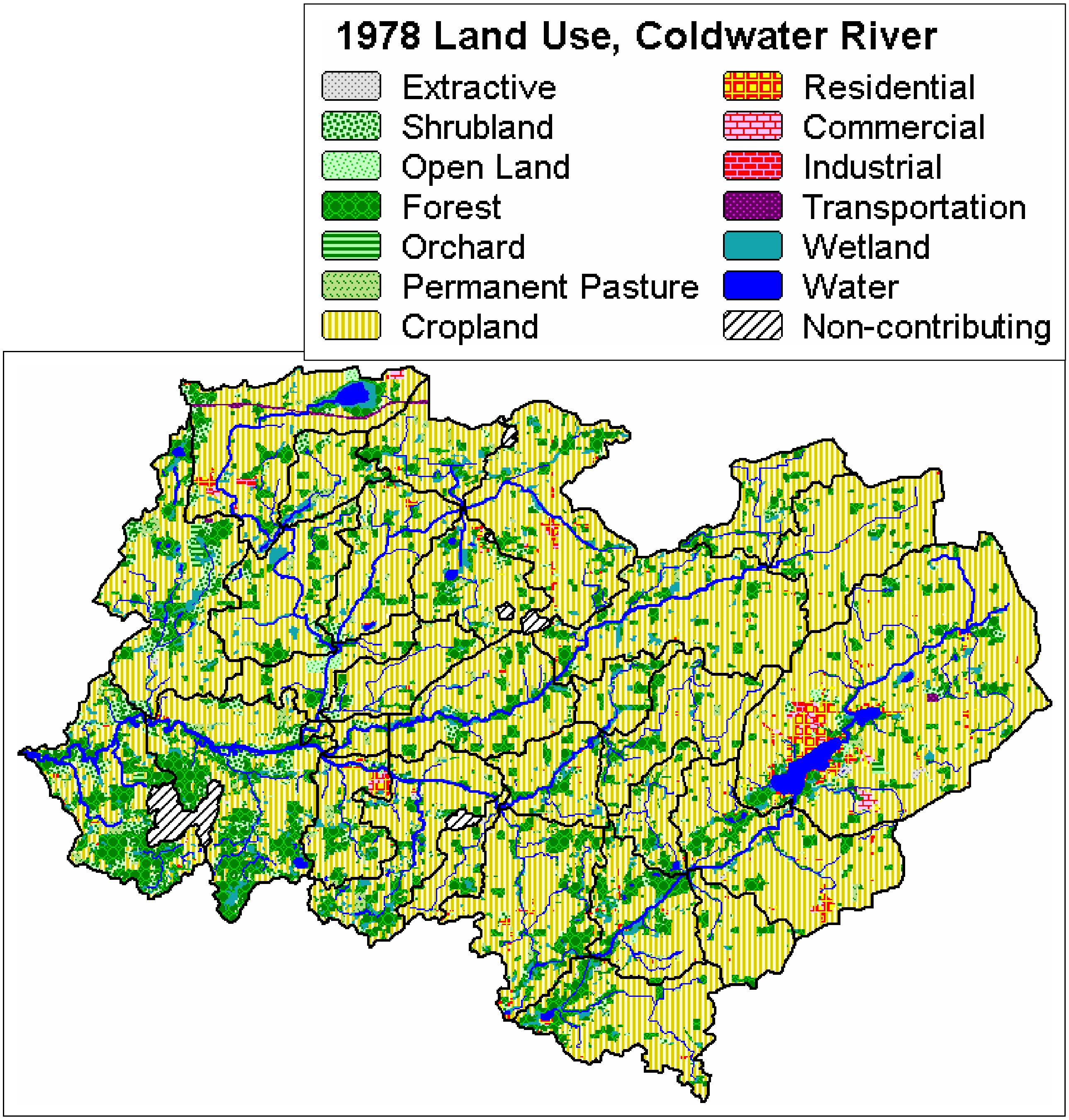


Figure 5: 1978 Land Use Data

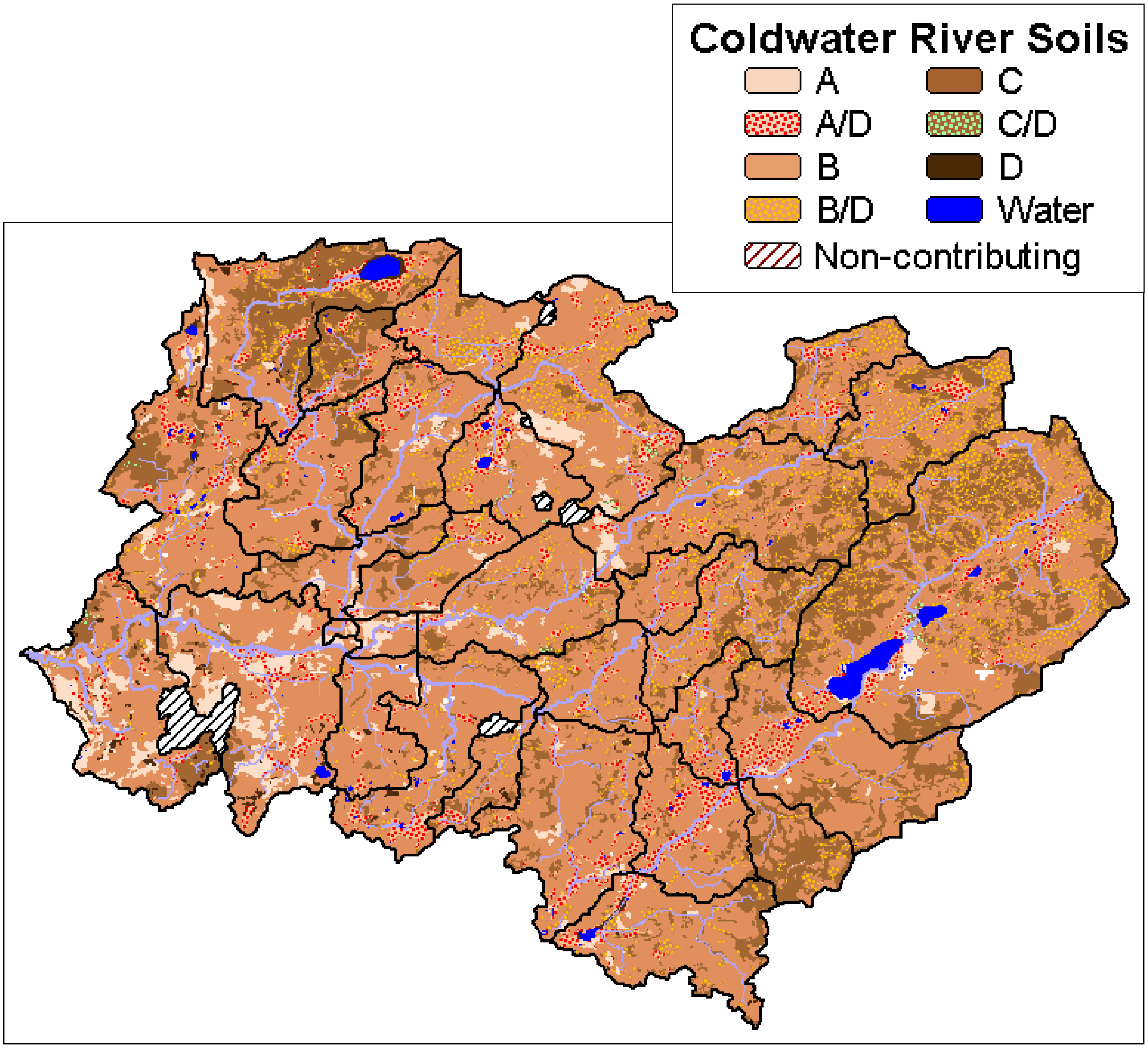


Figure 6: NRCS Soils Data

Table 1: Land Use by Subbasins (Land uses less than 0.5 percent are not listed because all percentages are rounded to the nearest percent)

Description	Scenario	Residential	Commercial	Industrial	Road	Pit	Cemeteries, Outdoor Rec.	Cropland	Orchard	Pasture	Herbaceous Openland	Forest	Water	Wetland
BC1	1800											100%		
	1978							59%			10%	32%		
BC2	1800											97%		3%
	1978						7%	75%		1%	5%	12%		
BC2T	1800											90%		10%
	1978							81%		1%	5%	12%		1%
BC3	1800											89%	1%	10%
	1978	1%						77%		2%	6%	11%		2%
BC4	1800											85%		15%
	1978	3%						77%		1%	2%	14%		4%
BC4Tn	1800											72%		28%
	1978				1%			74%		3%	2%	15%		5%
BC4Ts	1800											83%	2%	15%
	1978	1%						71%		2%	4%	15%	2%	5%
CR1	1800										17%	79%	1%	3%
	1978	1%						37%	1%	3%	17%	37%		4%
CR2	1800										2%	91%	1%	6%
	1978							45%		2%	12%	37%	1%	4%
CR2T	1800										8%	76%	1%	14%
	1978							60%	2%	1%	11%	19%	1%	5%
CR3	1800											98%		2%
	1978	5%	1%	1%				62%		3%	4%	21%		3%
CR4	1800											89%		11%
	1978							66%		2%	4%	22%		4%
CR5	1800											94%		6%
	1978	2%						70%		1%	2%	22%		3%
CR5Tn1	1800											92%		8%
	1978	1%						73%		1%	3%	17%		5%
CR5Tn2	1800											84%		16%
	1978							75%			2%	16%		7%
CR5Tn2T	1800											88%		12%
	1978							81%		1%	1%	15%		2%
CR5Ts	1800											93%		7%
	1978					1%		80%		1%	1%	15%		2%
CR6	1800											83%	5%	12%
	1978	2%						64%			3%	25%	1%	5%
CR6T	1800											93%	2%	5%
	1978	1%						74%			2%	19%	1%	2%
CR7	1800											94%		6%
	1978	2%						79%			2%	14%		2%
CR7Tn	1800											89%	1%	10%

Description	Scenario	Residential	Commercial	Industrial	Road	Pit	Cemeteries, Outdoor Rec.	Cropland	Orchard	Pasture	Herbaceous Openland	Forest	Water	Wetland
	1978	1%						72%		1%	4%	18%	1%	3%
CR7Ts	1800											99%		1%
	1978							88%			1%	10%		1%
CR8	1800											87%	4%	10%
	1978	5%	1%					73%			2%	11%	3%	2%
DC1	1800											100%		
	1978							73%		5%	7%	15%		
DC2	1800											93%		7%
	1978							72%		2%	3%	20%		3%
DC3	1800											89%		11%
	1978	1%						79%		1%	1%	15%		3%
DC4	1800											77%		23%
	1978							90%				8%		1%
DC4T	1800											71%		29%
	1978	1%						81%		1%	1%	14%		2%
NC	1800										1%	99%		
	1978	1%						33%	4%	4%	10%	46%		2%
PLC1	1800											84%		16%
	1978						1%	74%		2%	4%	16%		4%
PLC2	1800										6%	75%	4%	16%
	1978	1%	1%	1%	3%		1%	67%		1%	4%	14%	3%	4%
PLC2T	1800											82%		18%
	1978							68%		4%	7%	15%		6%
Overall Watershed	1800										2%	86%	1%	11%
	1978	1%						70%		1%	4%	18%	1%	3%

Model Results

Model results are illustrated in Figures 7 through 10 and detailed in Tables 2 through 5. Table 2 lists the computed peak flows from each subbasin. These values represent the peak flow contribution from the subbasins, not the flow in the river. Table 3 lists the computed peak flows at locations in the river. Table 4 lists the predicted runoff volumes from each subbasin. Table 5 lists the predicted runoff volumes at locations in the stream. Tables 4 and 5 do not include volumes for the Modified Drainage scenarios because the volumes are identical to the 1978 land use scenario.

The projected increases in stormwater runoff volume and peak flows conditions are due to changes in land use and loss of storage. The hydrologic model computes significant increases in runoff volumes and peak flows for both design storms. Peak flows and runoff volumes from the 50 percent chance 24-hour storm are predicted to increase more, on a percentage basis, than flows from the 4 percent chance, 24-hour storm. Increases in runoff volumes and peak flows from the 50 percent chance storm increase channel-forming flows, which will increase streambank erosion. Channel-forming flow is the flow that is most effective at shaping the channel. In a stable stream, the channel-forming flow has a one- to two-year recurrence interval and is the bankfull flow. Increases in runoff volumes and peak flows from the 4 percent chance storm will aggravate flooding. These projected increases can be moderated through the use of effective stormwater management techniques.

The Coldwater River watershed is partially in Kent County. A model stormwater ordinance adopted by Kent County calls for a maximum release rate of 0.05 cfs/acre for runoff from the 50 percent chance, 24-hour storm for Zone A areas, the most environmentally sensitive of the three zones. Currently, the average yield from this storm for the Coldwater River Watershed is 0.02 cfs/acre, with only one subbasin at 0.05 cfs/acre, as shown in Figure 11. The ordinance also calls for a maximum release rate of 0.13 cfs/acre for runoff from the 4 percent chance, 24-hour storm for Zones A and B. Currently, the average yield from this storm is 0.08 cfs/acre, with only four subbasins higher than 0.13 cfs/acre, as shown in Figure 12. Additional details are listed in Table 2. The developers of the watershed plan may want to consider whether the Kent County model ordinance standards will adequately protect the Coldwater River and its tributaries.

In our Pigeon River watershed study, we compared the flows from the 50 percent chance, 24-hour storm to flows based on a target yield of 0.0075 cfs/acre. This target yield was selected as criteria for a good trout fishery based on Mike Wiley and Paul Seelbach's November 1998 report titled "*An ecological assessment of opportunities for fisheries rehabilitation in the Pigeon River, Ottawa County*." Although clearly not the sole factor determining fish habitat quality, the good quality trout habitat corresponds to the locations with yields less than the target yield. Impaired habitat corresponds to locations with yields less than about 1.4 times the target yield. Locations with higher yields generally did not have trout. These same thresholds were applied to the Coldwater River results. For the 1800 scenario, one location would be classified as impaired, and the remaining sixteen locations would be good. For the 1978 scenario, all eight of the tributary locations would be poor, two of the locations in the upper Coldwater River would be classified as impaired, and the remaining seven locations would be good. Complete results are shown in Figure 13 and listed in Table 9.

Some stakeholders have speculated that the Coldwater River has become flashier because the upper watershed's drainage system, particularly in Ionia County, has become more efficient due to the installation and channelization of drains. The model can simulate this by increasing the time of concentration parameter for each watershed. Changing the times of concentration will change the computed peak flows but not the runoff volumes. An attempt to find some historical basis to modify time of concentration for each subbasin was unsuccessful, so the times of concentration for the 13 subbasins contributing to Bear Creek, Duck Creek, and Pratt Lake Creek were increased by 20 percent to simulate a less efficient drainage system. All other parameters in this Modified Drainage scenario are as specified in the 1978 scenario. The results are shown in Figures 14 and 15 and detailed in Tables 2 and 3. The changes in the times of concentration had little effect on peak flows. If excessive streambank erosion or increasing flooding are identified as problems in the Coldwater River watershed plan, the primary causes appear to be the changes in land use and loss of storage, not the installation and channelization of drains.

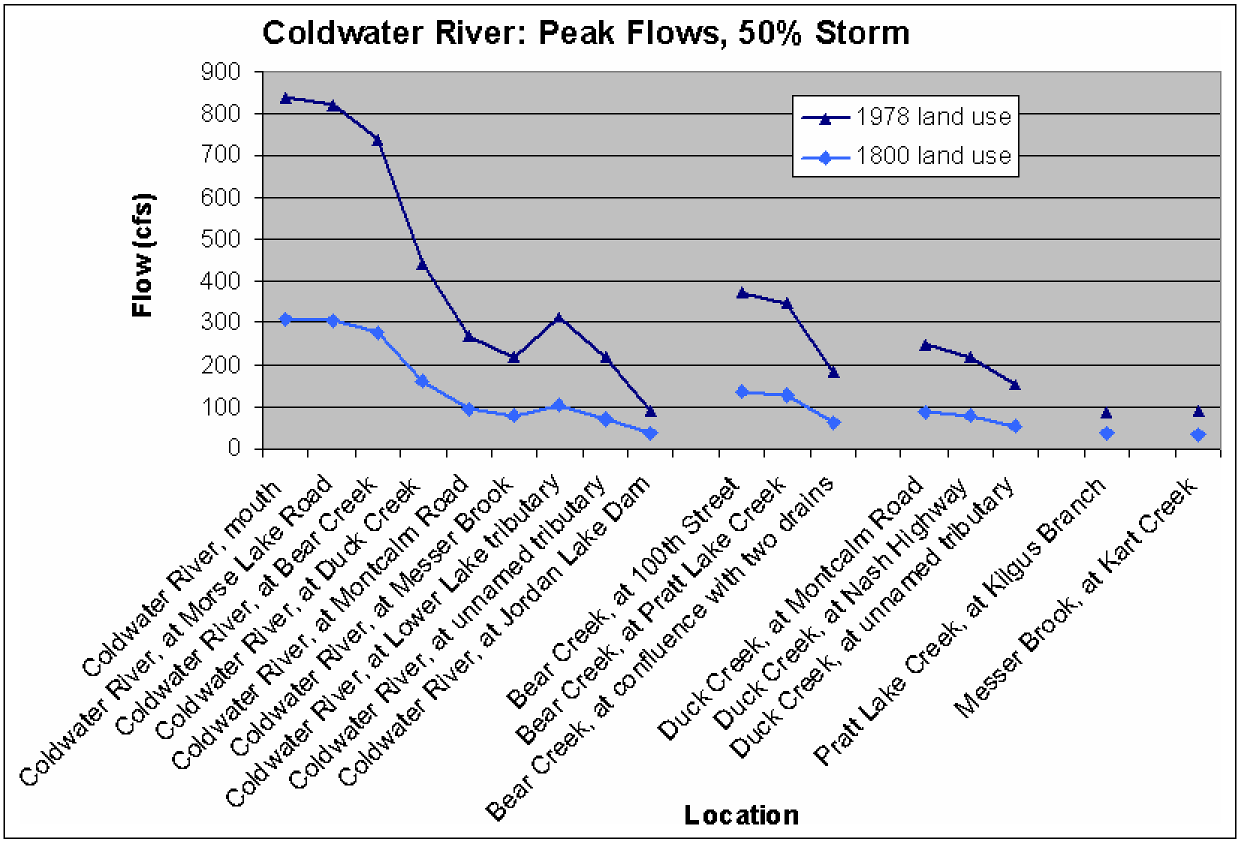


Figure 7: Predicted peak flows for river locations, 50 percent chance storm

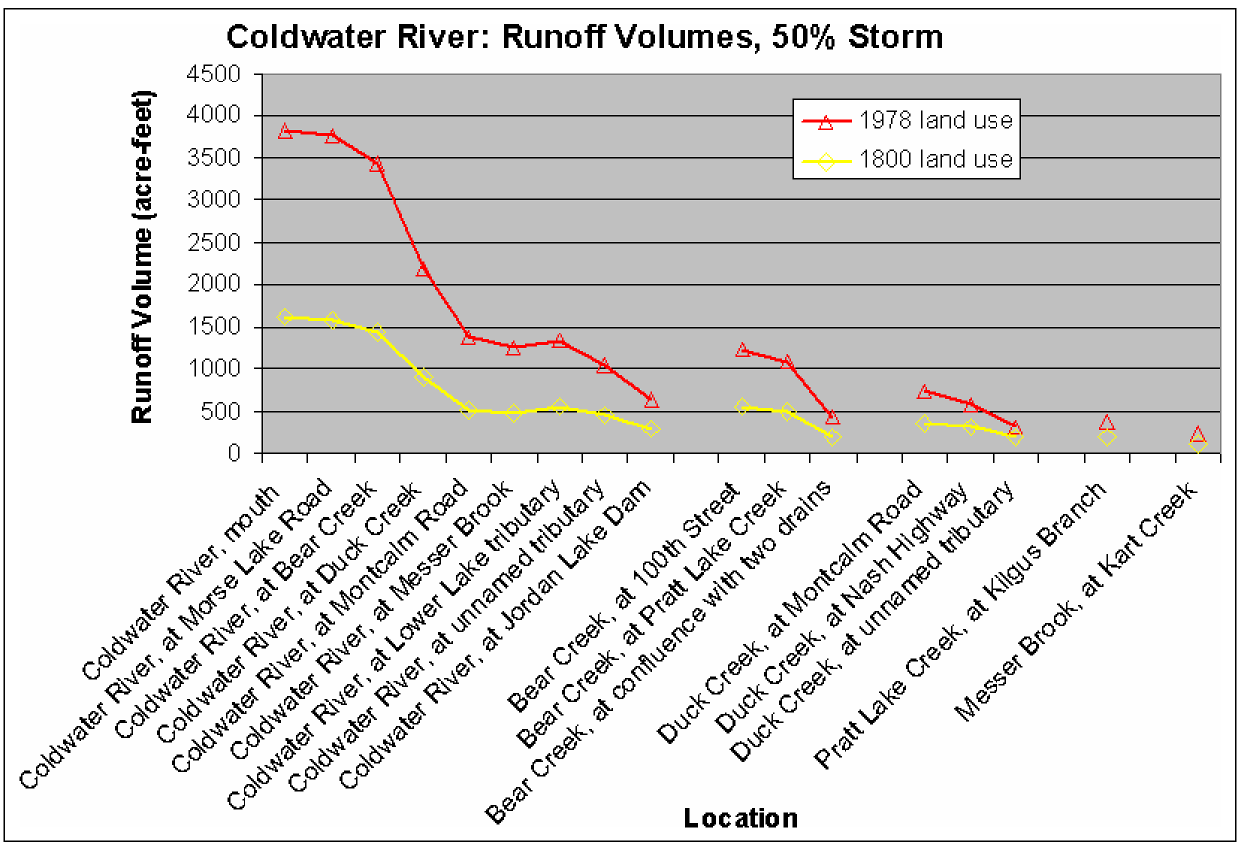


Figure 8: Predicted runoff volumes, 50 percent chance storm

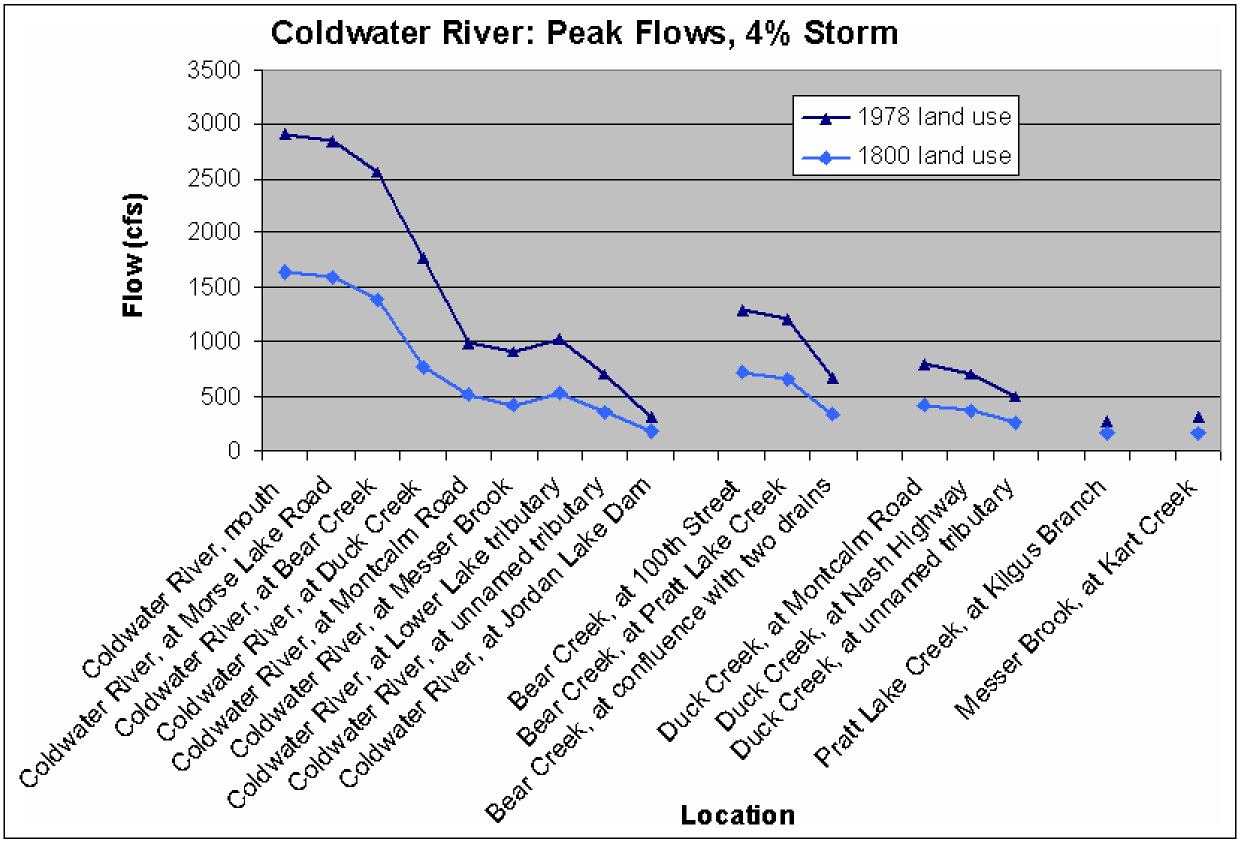


Figure 9: Predicted peak flows for river locations, 4 percent chance storm

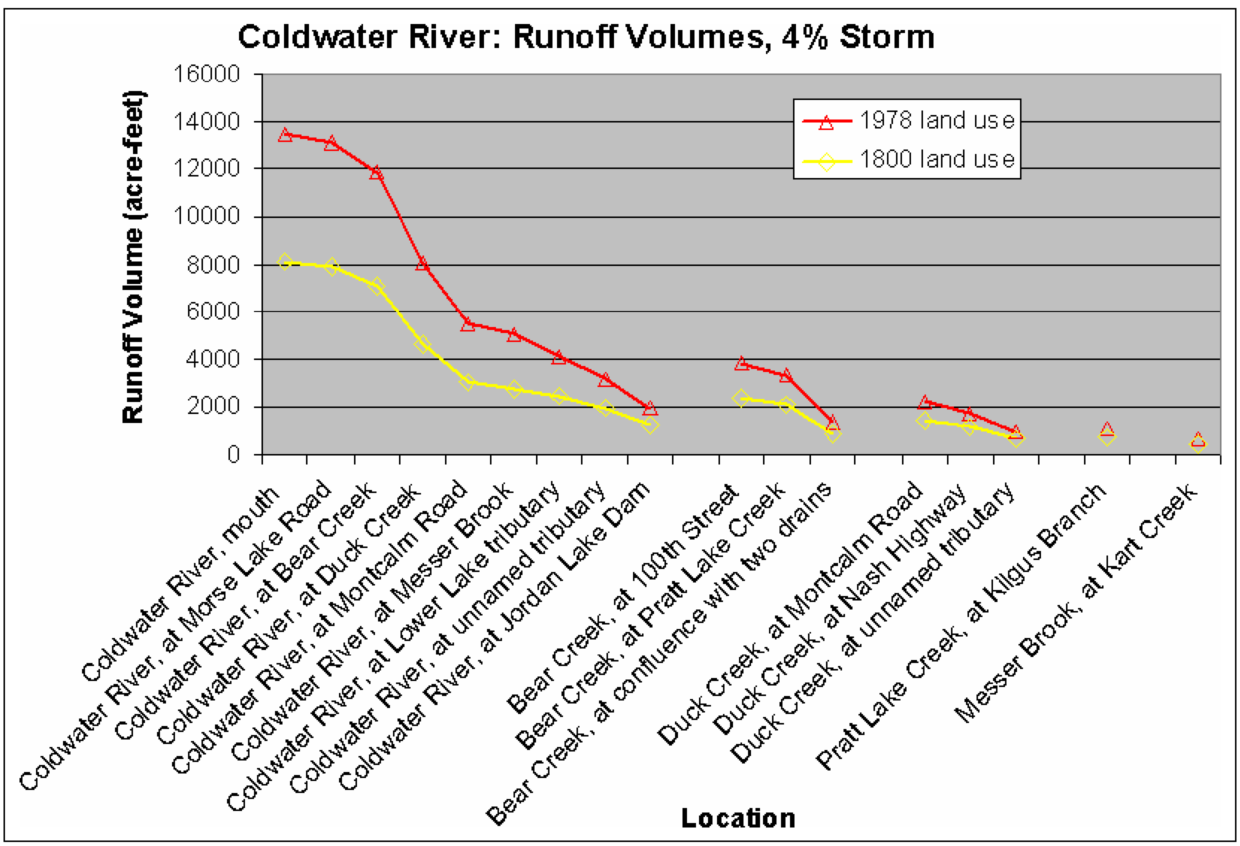


Figure 10: Predicted runoff volumes, 4 percent chance storm

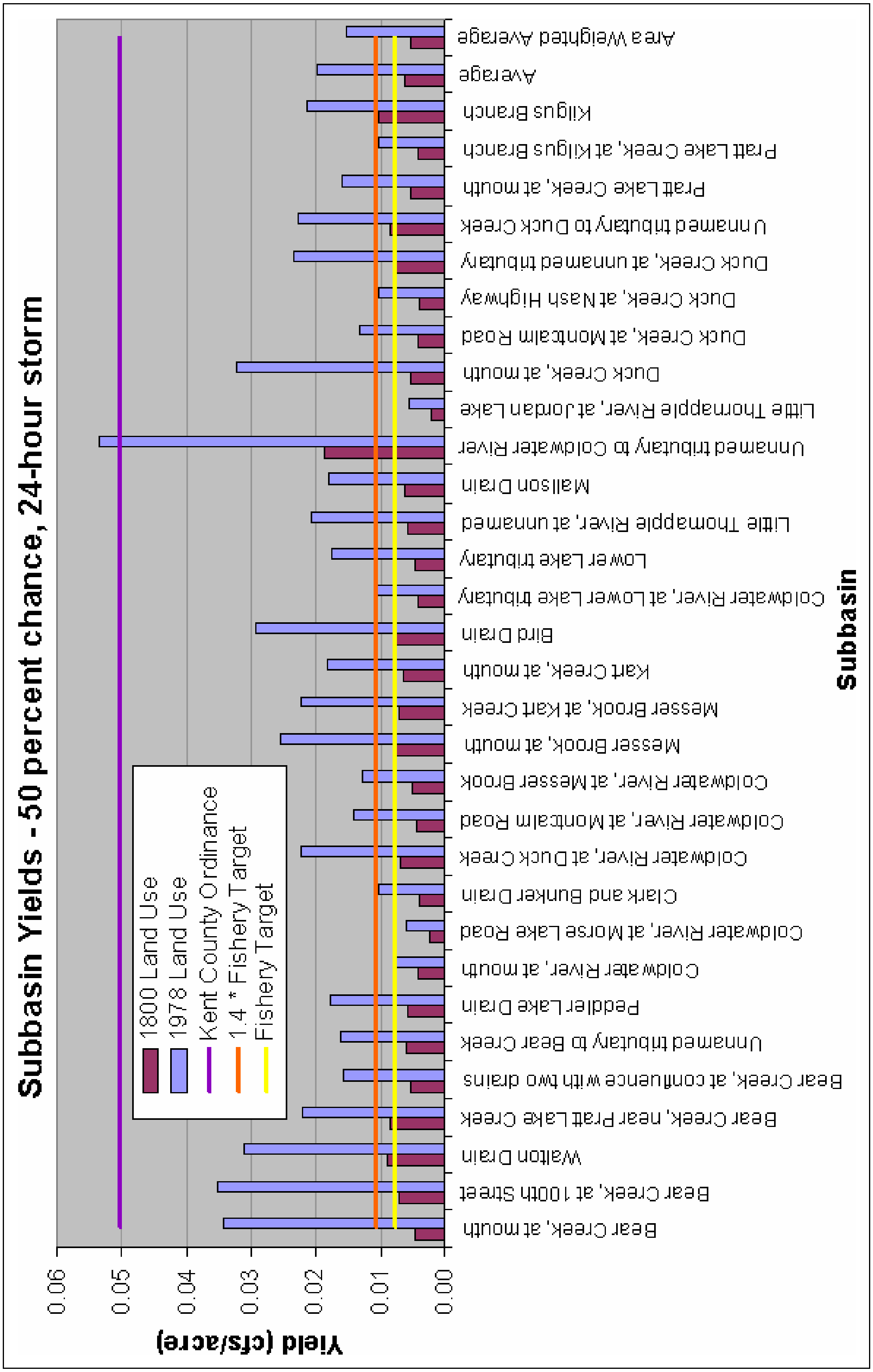


Figure 11: Subbasin Yields, 50 percent chance, 24-hour storm

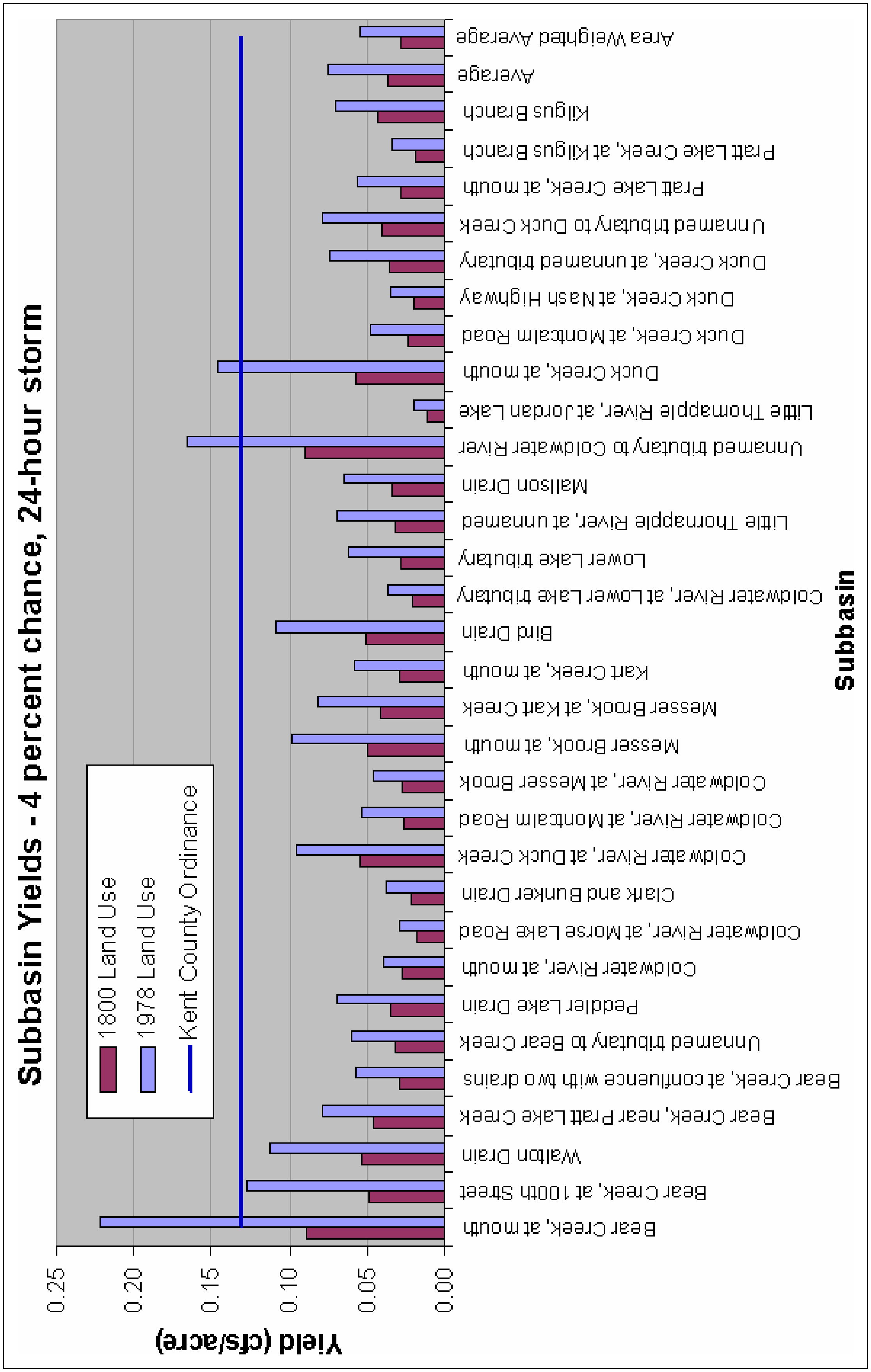


Figure 12: Subbasin Yields, 4 percent chance, 24-hour storm

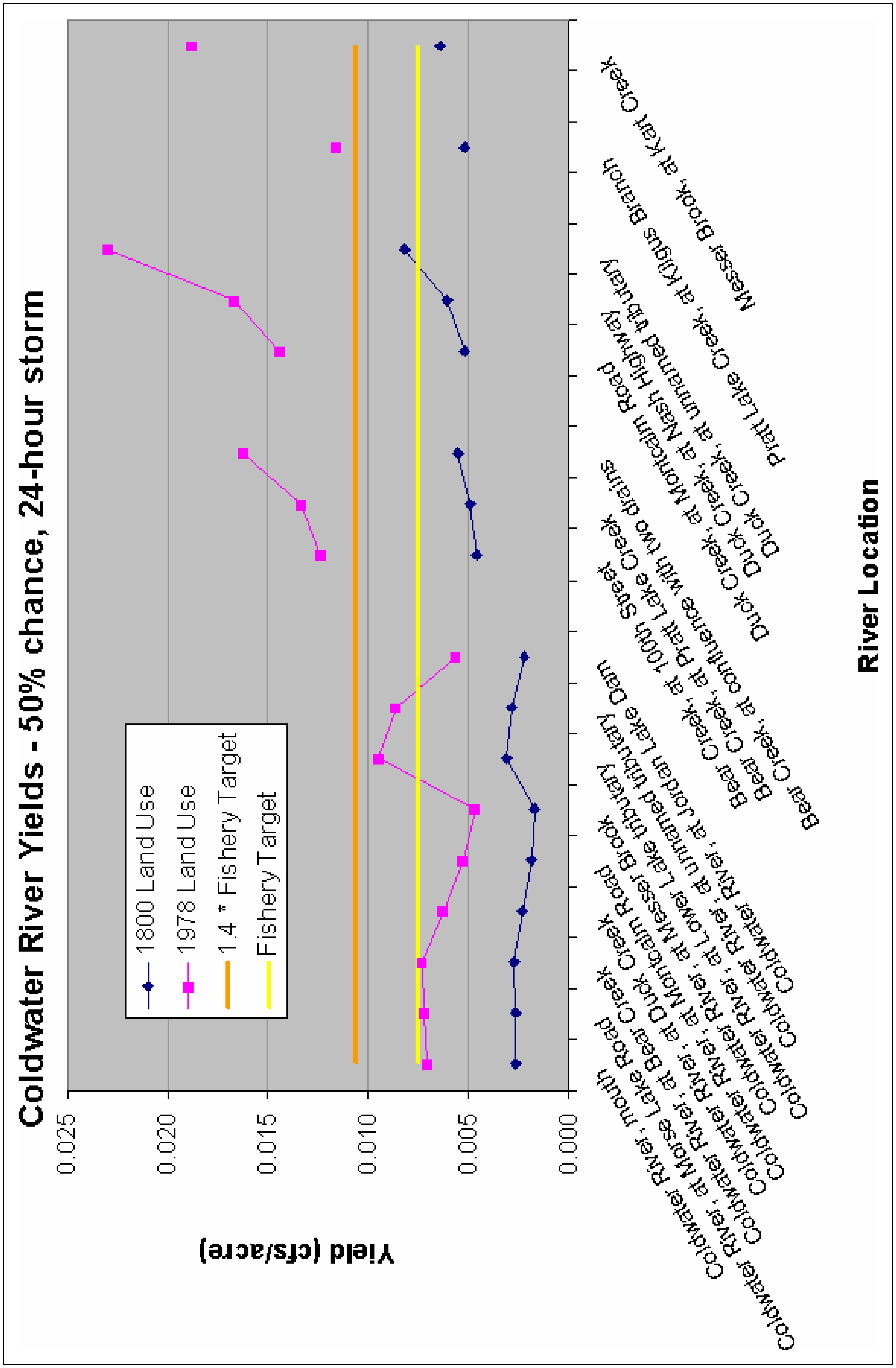


Figure 13: Coldwater River Yields, 50 percent chance, 24-hour storm

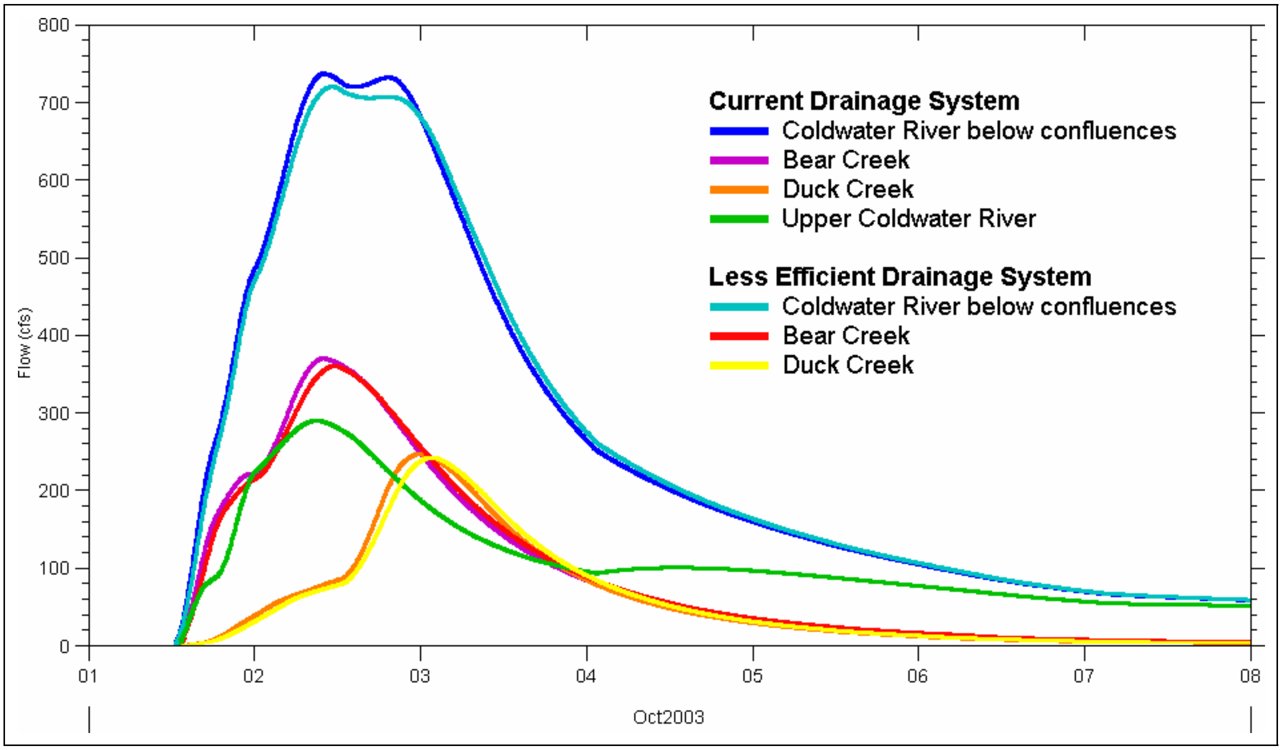


Figure 14: 50 percent chance, 24-hour storm hydrographs

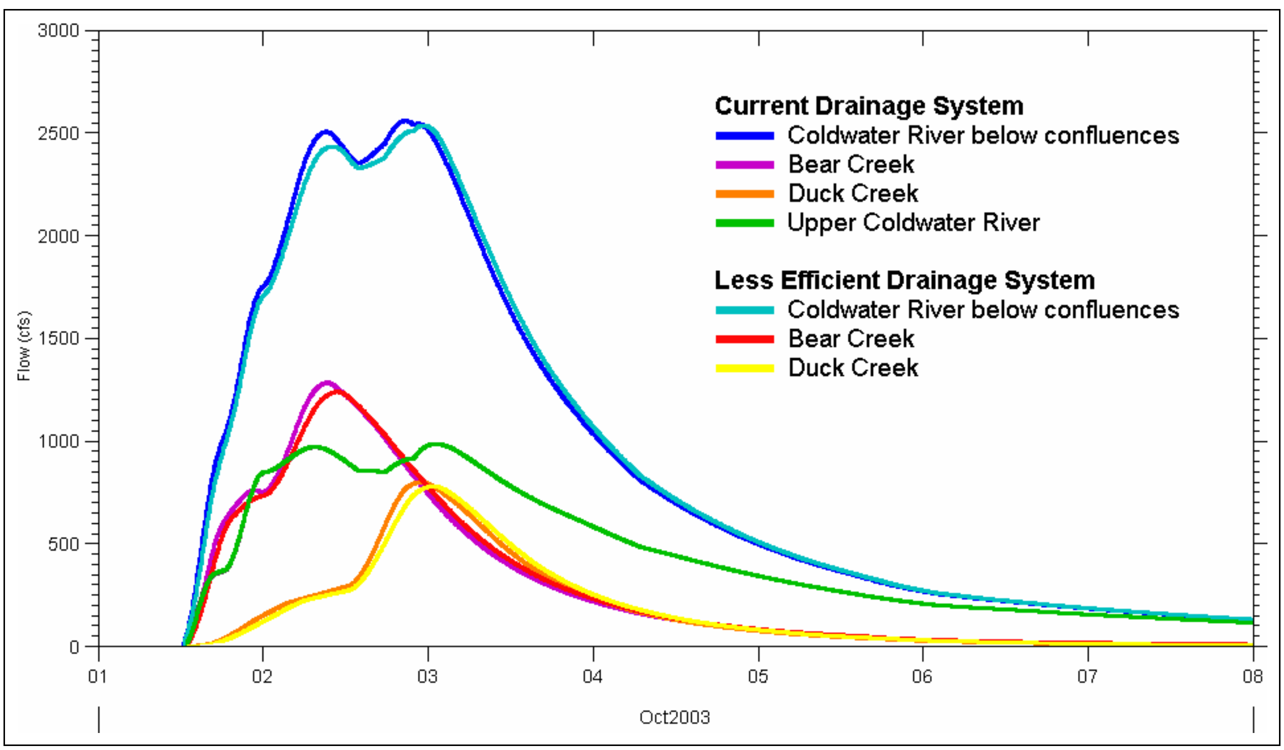


Figure 15: 4 percent chance, 24-hour storm hydrographs

Table 2: Peak flows per subbasin

Subbasin		Land Use Scenario	Peak Flow (cfs)		Yield (cfs/acre)	
ID	Description		50% chance storm	4% chance storm	50% chance storm	4% chance storm
BC1	Bear Creek, at mouth	1800	1	12	0.005	0.088
		1978	5	30	0.034	0.222
		Mod. drainage	5	30	0.034	0.222
BC2	Bear Creek, at 100th Street	1800	14	98	0.007	0.049
		1978	70	255	0.035	0.128
		Mod. drainage	69	246	0.035	0.123
BC2T	Walton Drain	1800	19	111	0.009	0.053
		1978	65	236	0.031	0.112
		Mod. drainage	65	230	0.031	0.109
BC3	Bear Creek, near Pratt Lake Creek	1800	28	153	0.008	0.046
		1978	74	264	0.022	0.079
		Mod. drainage	73	260	0.022	0.078
BC4	Bear Creek, at confluence with two drains	1800	30	168	0.005	0.029
		1978	91	330	0.016	0.057
		Mod. drainage	90	326	0.016	0.056
BC4Tn	Unnamed tributary to Bear Creek	1800	15	76	0.006	0.031
		1978	40	145	0.016	0.059
		Mod. drainage	40	143	0.016	0.058
BC4Ts	Peddler Lake Drain	1800	16	98	0.006	0.035
		1978	50	194	0.018	0.069
		Mod. drainage	50	192	0.018	0.068
CR1	Coldwater River, at mouth	1800	21	138	0.004	0.027
		1978	40	197	0.008	0.039
CR2	Coldwater River, at Morse Lake Road	1800	16	120	0.002	0.018
		1978	40	197	0.006	0.029
CR2T	Clark and Bunker Drain	1800	25	134	0.004	0.021
		1978	64	237	0.010	0.038
CR3	Coldwater River, at Duck Creek	1800	17	128	0.007	0.054
		1978	53	228	0.022	0.095
CR4	Coldwater River, at Montcalm Road	1800	18	109	0.004	0.026
		1978	58	219	0.014	0.053
CR5	Coldwater River, at Messer Brook	1800	26	143	0.005	0.027
		1978	68	241	0.013	0.045
CR5Tn1	Messer Brook, at mouth	1800	18	115	0.008	0.050
		1978	58	226	0.025	0.098
CR5Tn2	Messer Brook, at Kart Creek	1800	10	58	0.007	0.041
		1978	31	114	0.022	0.082
CR5Tn2T	Kart Creek, at mouth	1800	22	102	0.006	0.029
		1978	64	204	0.018	0.058
CR5Ts	Bird Drain	1800	11	66	0.008	0.050
		1978	38	142	0.029	0.108
CR6	Coldwater River, at Lower Lake tributary	1800	13	67	0.004	0.021
		1978	34	121	0.011	0.037
CR6T	Lower Lake tributary	1800	20	120	0.005	0.028

Subbasin		Land Use Scenario	Peak Flow (cfs)		Yield (cfs/acre)	
ID	Description		50% chance storm	4% chance storm	50% chance storm	4% chance storm
		1978	75	265	0.017	0.061
CR7	Little Thornapple River, at unnamed tributary	1800	34	184	0.006	0.031
		1978	121	405	0.021	0.069
CR7Tn	Mallson Drain	1800	10	54	0.006	0.033
		1978	29	106	0.018	0.065
CR7Ts	Unnamed tributary to Coldwater River	1800	36	176	0.019	0.090
		1978	104	323	0.054	0.166
CR8	Little Thornapple River, at Jordan Lake Dam	1800	36	168	0.002	0.010
		1978	91	310	0.006	0.019
DC1	Duck Creek, at mouth	1800	3	34	0.005	0.057
		1978	19	87	0.032	0.147
		Mod. drainage	19	85	0.032	0.142
DC2	Duck Creek, at Montcalm Road	1800	17	99	0.004	0.024
		1978	55	196	0.013	0.047
		Mod. drainage	54	192	0.013	0.046
DC3	Duck Creek, at Nash Highway	1800	25	121	0.004	0.019
		1978	65	217	0.010	0.034
		Mod. drainage	63	210	0.010	0.033
DC4	Duck Creek, at unnamed tributary	1800	35	153	0.008	0.036
		1978	100	314	0.023	0.073
		Mod. drainage	99	306	0.023	0.072
DC4T	Unnamed tributary to Duck Creek	1800	20	96	0.008	0.040
		1978	54	189	0.023	0.079
		Mod. drainage	54	186	0.023	0.078
PLC1	Pratt Lake Creek, at mouth	1800	20	108	0.005	0.028
		1978	62	217	0.016	0.056
		Mod. drainage	61	214	0.016	0.055
PLC2	Pratt Lake Creek, at Kilgus Branch	1800	25	109	0.004	0.019
		1978	60	192	0.010	0.033
		Mod. drainage	58	187	0.010	0.032
PLC2T	Kilgus Branch	1800	18	76	0.010	0.044
		1978	37	123	0.021	0.071
		Mod. drainage	37	121	0.021	0.070
Averages		1800			0.006	0.037
		1978			0.020	0.075
Area-Weighted Averages		1800			0.005	0.028
		1978			0.015	0.055

Table 3: Peak flows in Coldwater River

River Location		Drainage	Land Use	Peak Flow (cfs)		Yield (cfs/acre)	
ID	Description	Area	Scenario	50%	4%	50%	4%
J1	Coldwater River, mouth	187	1800	311	1634	0.003	0.014
			1978	840	2908	0.007	0.024
			Mod. drainage	819	2823	0.007	0.024
J2	Coldwater River, at Morse Lake Road	179	1800	305	1585	0.003	0.014
			1978	822	2840	0.007	0.025
			Mod. drainage	802	2757	0.007	0.024
J3aBC1	Coldwater River, at Bear Creek	158	1800	279	1381	0.003	0.014
			1978	737	2560	0.007	0.025
			Mod. drainage	720	2537	0.007	0.025
J3bDC1	Coldwater River, at Duck Creek	111	1800	161	764	0.002	0.011
			1978	443	1771	0.006	0.025
			Mod. drainage	425	1765	0.006	0.025
J4	Coldwater River, at Montcalm Road	80	1800	95	505	0.002	0.010
			1978	270	980	0.005	0.019
J5	Coldwater River, at Messer Brook	73	1800	80	409	0.002	0.009
			1978	220	911	0.005	0.019
J6	Coldwater River, at Lower Lake tributary	52	1800	102	522	0.003	0.016
			1978	314	1019	0.009	0.031
J7	Coldwater River, at unnamed tributary	40	1800	72	356	0.003	0.014
			1978	220	707	0.009	0.028
J8	Coldwater River, at Jordan Lake Dam	25	1800	36	168	0.002	0.010
			1978	91	310	0.006	0.019
JBC2	Bear Creek, at 100th Street	47	1800	137	712	0.005	0.024
			1978	370	1284	0.012	0.043
			Mod. drainage	360	1240	0.012	0.041
JBC3PLC1	Bear Creek, at Pratt Lake Creek	40	1800	126	648	0.005	0.025
			1978	345	1205	0.013	0.047
			Mod. drainage	339	1173	0.013	0.045
JBC4	Bear Creek, at confluence with two drains	17	1800	61	340	0.005	0.031
			1978	180	661	0.016	0.060
			Mod. drainage	178	650	0.016	0.059
JCRT	Messer Brook, at Kart Creek	8	1800	32	153	0.006	0.031
			1978	92	295	0.019	0.060
JDC2	Duck Creek, at Montcalm Road	27	1800	89	420	0.005	0.024
			1978	247	800	0.014	0.047
			Mod. drainage	243	780	0.014	0.045
JDC3	Duck Creek, at Nash Highway	20	1800	79	366	0.006	0.028
			1978	217	705	0.017	0.054
			Mod. drainage	214	687	0.016	0.053
JDC4	Duck Creek, at unnamed tributary	10	1800	55	247	0.008	0.037
			1978	153	492	0.023	0.074
			Mod. drainage	151	477	0.023	0.071
JPLC2	Pratt Lake Creek, at Kilgus Branch	12	1800	39	166	0.005	0.022
			1978	87	275	0.012	0.036
			Mod. drainage	82	258	0.011	0.034
Averages			1800			0.004	0.020
			1978			0.011	0.037
Area-Weighted Averages			1800			0.003	0.015
			1978			0.008	0.028

Table 4: Runoff volumes per subbasin

Subbasin		Land Use Scenario	Runoff Volume (acre-feet)	
ID	Description		50% chance storm	4% chance storm
BC1	Bear Creek, at mouth	1800	1	6
		1978	2	11
BC2	Bear Creek, at 100th Street	1800	24	132
		1978	72	236
BC2T	Walton Drain	1800	31	151
		1978	80	257
BC3	Bear Creek, near Pratt Lake Creek	1800	52	248
		1978	135	422
BC4	Bear Creek, at confluence with two drains	1800	93	435
		1978	219	702
BC4Tn	Unnamed tributary to Bear Creek	1800	50	209
		1978	98	307
BC4Ts	Peddler Lake Drain	1800	42	204
		1978	104	338
CR1	Coldwater River, at mouth	1800	54	314
		1978	104	435
CR2	Coldwater River, at Morse Lake Road	1800	55	369
		1978	131	562
CR2T	Clark and Bunker Drain	1800	101	476
		1978	226	741
CR3	Coldwater River, at Duck Creek	1800	23	141
		1978	77	264
CR4	Coldwater River, at Montcalm Road	1800	55	285
		1978	153	497
CR5	Coldwater River, at Messer Brook	1800	69	360
		1978	199	639
CR5Tn1	Messer Brook, at mouth	1800	34	166
		1978	90	284
CR5Tn2	Messer Brook, at Kart Creek	1800	24	108
		1978	59	181
CR5Tn2T	Kart Creek, at mouth	1800	82	324
		1978	163	479
CR5Ts	Bird Drain	1800	21	98
		1978	51	161
CR6	Coldwater River, at Lower Lake tributary	1800	59	261
		1978	129	406
CR6T	Lower Lake tributary	1800	65	316
		1978	174	544
CR7	Little Thornapple River, at unnamed tributary	1800	93	440
		1978	259	781
CR7Tn	Mallson Drain	1800	30	132
		1978	65	204
CR7Ts	Unnamed tributary to Coldwater River	1800	46	180
		1978	104	291
CR8	Little Thornapple River, at Jordan Lake Dam	1800	285	1221
		1978	629	1960

Subbasin		Land Use Scenario	Runoff Volume (acre-feet)	
ID	Description		50% chance storm	4% chance storm
DC1	Duck Creek, at mouth	1800	3	27
		1978	15	58
DC2	Duck Creek, at Montcalm Road	1800	57	288
		1978	156	500
DC3	Duck Creek, at Nash Highway	1800	120	521
		1978	271	827
DC4	Duck Creek, at unnamed tributary	1800	121	440
		1978	209	603
DC4T	Unnamed tributary to Duck Creek	1800	59	227
		1978	100	308
PLC1	Pratt Lake Creek, at mouth	1800	65	300
		1978	160	494
PLC2	Pratt Lake Creek, at Kilgus Branch	1800	139	543
		1978	282	819
PLC2T	Kilgus Branch	1800	51	182
		1978	88	250

Table 5: Runoff volumes in Coldwater River

River Location		Drainage Area (square miles)	Land Use Scenario	Runoff Volume (acre-feet)	
ID	Description			50% chance storm	4% chance storm
J1	Coldwater River, mouth	187	1800	1614	8101
			1978	3829	13459
J2	Coldwater River, at Morse Lake Road	179	1800	1581	7859
			1978	3762	13113
J3aBC1	Coldwater River, at Bear Creek	158	1800	1439	7061
			1978	3430	11867
J3bDC1	Coldwater River, at Duck Creek	111	1800	896	4665
			1978	2195	8045
J4	Coldwater River, at Montcalm Road	80	1800	519	3035
			1978	1375	5501
J5	Coldwater River, at Messer Brook	73	1800	474	2785
			1978	1243	5049
J6	Coldwater River, at Lower Lake tributary	52	1800	555	2472
			1978	1325	4094
J7	Coldwater River, at unnamed tributary	40	1800	445	1942
			1978	1044	3201
J8	Coldwater River, at Jordan Lake Dam	25	1800	285	1221
			1978	629	1960
JBC2	Bear Creek, at 100th Street	47	1800	544	2396
			1978	1236	3817
JBC3PLC1	Bear Creek, at Pratt Lake Creek	40	1800	489	2115
			1978	1084	3326
JBC4	Bear Creek, at confluence with two drains	17	1800	184	848
			1978	422	1347
JCRT	Messer Brook, at Kart Creek	8	1800	105	432
			1978	222	660
JDC2	Duck Creek, at Montcalm Road	27	1800	354	1472
			1978	733	2235
JDC3	Duck Creek, at Nash Highway	20	1800	299	1187
			1978	579	1738
JDC4	Duck Creek, at unnamed tributary	10	1800	180	667
			1978	309	911
JPLC2	Pratt Lake Creek, at Kilgus Branch	12	1800	190	725
			1978	370	1070

Appendices

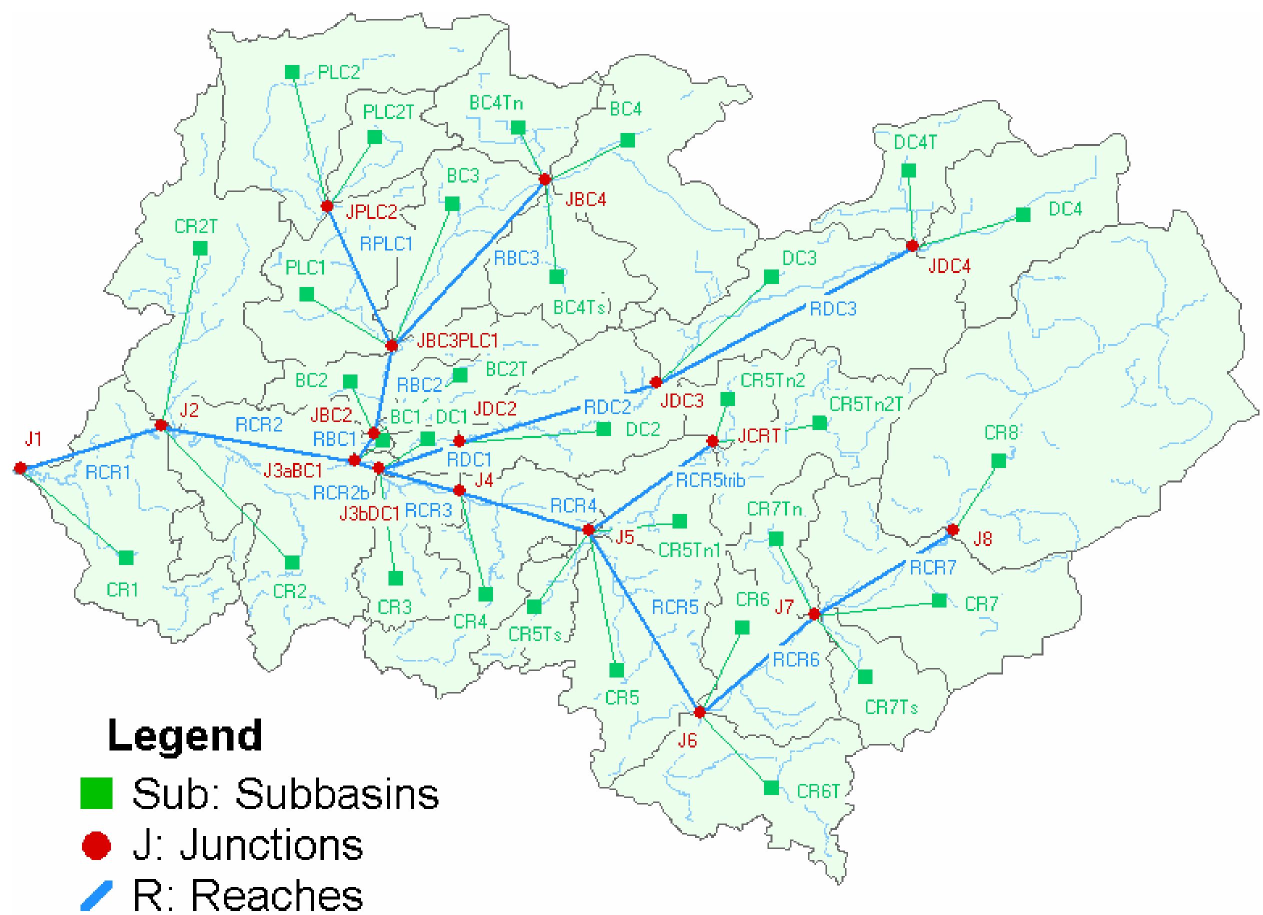
Appendix A: Coldwater River Hydrologic Model Parameters

This appendix is provided so that the model may be recreated. Table A1 provides the design rainfall values specific to the region of the state where the Coldwater River is located. Figure A1 summarizes the hydrologic elements in the HEC-HMS model. Tables A2 and A3 provide the parameters that were specified for each of these hydrologic elements. The initial loss field in HEC-HMS is left blank so that the default equation based on the curve number is used. Tables A4 and A5 provide the reach parameters for the routing method. The control specified in HEC-HMS was for an eight day duration using a five minute time interval.

Table A1: Design Rainfall Values

SCS Type II Precipitation Event	Precipitation*
50% chance (2-year), 24-hour storm	2.18 inches
4% chance (25-year), 24-hour storm	3.76 inches

*standard values were multiplied by 0.92 to account for the watershed size



BC1	Bear Creek, at mouth	CR5Ts	Bird Drain
BC2	Bear Creek, at 100th Street	CR6	Coldwater River, at Lower Lake tributary
BC2T	Walton Drain	CR6T	Lower Lake tributary
BC3	Bear Creek, near Pratt Lake Creek	CR7	Little Thornapple River, at unnamed tributary
BC4	Bear Creek, at confluence with two drains	CR7Tn	Mallson Drain
BC4Tn	Unnamed tributary to Bear Creek	CR7Ts	Unnamed tributary to Coldwater River
BC4Ts	Peddler Lake Drain	CR8	Little Thornapple River, at Jordan Lake Dam
CR1	Coldwater River, at mouth	DC1	Duck Creek, at mouth
CR2	Coldwater River, at Morse Lake Road	DC2	Duck Creek, at Montcalm Road
CR2T	Clark and Bunker Drain	DC3	Duck Creek, at Nash Highway
CR3	Coldwater River, at Duck Creek	DC4	Duck Creek, at unnamed tributary
CR4	Coldwater River, at Montcalm Road	DC4T	Unnamed tributary to Duck Creek
CR5	Coldwater River, at Messer Brook	PLC1	Pratt Lake Creek, at mouth
CR5Tn1	Messer Brook, at mouth	PLC2	Pratt Lake Creek, at Kilgus Branch
CR5Tn2	Messer Brook, at Kart Creek	PLC2T	Kilgus Branch
CR5Tn2T	Kart Creek, at mouth		

Figure A1: Hydrologic Elements defined for HEC-HMS model

Table A2: Subbasin Parameters – Area, Curve Number, Initial Loss

Subbasins		Drainage Area (sq. mi.)	Runoff Curve Number		Initial Loss
ID	Description		1800	1978	
NC	Non-contributing	1.88			
BC1	Bear Creek, at mouth	0.21	56.6	66.5	Default
BC2	Bear Creek, at 100th Street	3.12	63.0	73.9	Default
BC2T	Walton Drain	3.29	64.4	74.6	Default
BC3	Bear Creek, near Pratt Lake Creek	5.24	64.9	75.3	Default
BC4	Bear Creek, at confluence with two drains	9.04	65.2	74.5	Default
BC4Tn	Unnamed tributary to Bear Creek	3.82	67.5	75.3	Default
BC4Ts	Peddler Lake Drain	4.41	64.5	74.2	Default
CR1	Coldwater River, at mouth	7.93	62.0	67.5	Default
CR2	Coldwater River, at Morse Lake Road	10.54	60.2	67.0	Default
CR2T	Clark and Bunker Drain	9.86	65.3	73.8	Default
CR3	Coldwater River, at Duck Creek	3.74	61.3	72.5	Default
CR4	Coldwater River, at Montcalm Road	6.52	63.6	74.1	Default
CR5	Coldwater River, at Messer Brook	8.27	63.5	74.4	Default
CR5Tn1	Messer Brook, at mouth	3.59	64.5	74.9	Default
CR5Tn2	Messer Brook, at Kart Creek	2.18	65.7	76.0	Default
CR5Tn2T	Kart Creek, at mouth	5.48	68.9	77.2	Default
CR5Ts	Bird Drain	2.05	65.1	74.8	Default
CR6	Coldwater River, at Lower Lake tributary	5.05	66.6	75.3	Default
CR6T	Lower Lake tributary	6.76	64.7	75.3	Default
CR7	Little Thornapple River, at unnamed tributary	9.20	65.1	76.5	Default
CR7Tn	Mallson Drain	2.54	66.5	75.3	Default
CR7Ts	Unnamed tributary to Coldwater River	3.04	68.9	79.3	Default
CR8	Little Thornapple River, at Jordan Lake Dam #1922	25.29	70.0	77.7	Default
DC1	Duck Creek, at mouth	0.93	57.7	69.9	Default
DC2	Duck Creek, at Montcalm Road	6.47	63.9	74.4	Default
DC3	Duck Creek, at Nash Highway	9.91	67.1	76.3	Default
DC4	Duck Creek, at unnamed tributary	6.69	71.0	77.9	Default
DC4T	Unnamed tributary to Duck Creek	3.74	69.4	75.8	Default
PLC1	Pratt Lake Creek, at mouth	6.05	65.7	75.6	Default
PLC2	Pratt Lake Creek, at Kilgus Branch	9.07	70.1	78.4	Default
PLC2T	Kilgus Branch	2.72	71.4	78.4	Default
	Total	186.78			

Table A3: Subbasin Parameters – Times of Concentration and Storage Coefficients

Subbasins		Land Use Scenario	Time of Concentration (hours)	Storage Coefficient	
ID	Description			50% chance, 24-hour storm	4% chance, 24-hour storm
BC1	Bear Creek, at mouth	1800	1.33	1.33	1.33
		1978		1.33	1.33
BC2	Bear Creek, at 100th Street	1800	5.05	10.46	5.05
		1978		7.83	5.05
BC2T	Walton Drain	1800	5.69	9.54	6.73
		1978		8.03	6.38
BC3	Bear Creek, near Pratt Lake Creek	1800	7.25	12.03	12.31
		1978		10.28	10.92
BC4	Bear Creek, at confluence with two drains	1800	9.98	26.00	18.34
		1978		20.38	15.81
BC4Tn	Unnamed tributary to Bear Creek	1800	9.80	29.73	18.98
		1978		22.28	15.90
BC4Ts	Peddler Lake Drain	1800	7.07	21.02	14.87
		1978		14.88	12.22
CR1	Coldwater River, at mouth	1800	9.28	21.20	20.65
		1978		16.69	16.25
CR2	Coldwater River, at Morse Lake Road	1800	13.40	30.14	27.53
		1978		25.15	22.99
CR2T	Clark and Bunker Drain	1800	15.36	36.82	30.28
		1978		30.56	25.87
CR3	Coldwater River, at Duck Creek	1800	4.38	7.06	8.65
		1978		5.62	7.13
CR4	Coldwater River, at Montcalm Road	1800	10.37	25.74	20.69
		1978		20.51	17.20
CR5	Coldwater River, at Messer Brook	1800	13.95	20.72	23.37
		1978		18.83	20.96
CR5Tn1	Messer Brook, at mouth	1800	4.86	12.89	9.63
		1978		8.83	8.07
CR5Tn2	Messer Brook, at Kart Creek	1800	6.32	18.51	13.23
		1978		12.98	11.02
CR5Tn2T	Kart Creek, at mouth	1800	13.76	31.91	19.32
		1978		26.42	17.75
CR5Ts	Bird Drain	1800	5.24	13.09	7.65
		1978		9.26	6.92
CR6	Coldwater River, at Lower Lake tributary	1800	17.25	41.53	32.77
		1978		34.70	28.32
CR6T	Lower Lake tributary	1800	9.80	27.68	17.19
		1978		20.93	15.16
CR7	Little Thornapple River, at unnamed tributary	1800	10.41	22.39	15.29
		1978		18.04	13.81
CR7Tn	Mallson Drain	1800	8.72	25.14	16.45
		1978		18.88	13.99
CR7Ts	Unnamed tributary to Coldwater River	1800	4.45	6.43	5.52
		1978		5.68	5.24

Subbasins		Land Use Scenario	Time of Concentration (hours)	Storage Coefficient	
ID	Description			50% chance, 24-hour storm	4% chance, 24-hour storm
CR8	Little Thornapple River, at Jordan Lake Dam #1922	1800	31.51	122.54	84.12
		1978		94.07	69.44
DC1	Duck Creek, at mouth	1800	3.13	3.13	3.13
		1978		3.13	3.13
DC2	Duck Creek, at Montcalm Road	1800	13.28	28.10	22.33
		1978		23.38	19.96
DC3	Duck Creek, at Nash Highway	1800	20.46	45.49	37.33
		1978		38.64	32.80
DC4	Duck Creek, at unnamed tributary	1800	11.00	30.36	14.80
		1978		23.73	13.72
DC4T	Unnamed tributary to Duck Creek	1800	8.09	25.20	12.38
		1978		18.26	11.13
PLC1	Pratt Lake Creek, at mouth	1800	10.86	28.06	20.08
		1978		22.37	17.31
PLC2	Pratt Lake Creek, at Kilgus Branch	1800	21.05	59.13	44.71
		1978		48.53	38.51
PLC2T	Kilgus Branch	1800	9.02	23.94	18.05
		1978		18.65	15.30

Table A4: Channel Reach Parameters

	Reach	Lag (minutes)
RBC1	Bear Creek, to Coldwater River	72
RBC2	Bear Creek, to 100th Street	173
RBC3	Bear Creek, to near Pratt Lake Creek	505
RCR1	Coldwater River, to mouth	860
RCR2	Coldwater River, to Morse Lake Road	619
RCR2b	Coldwater River, to Bear Creek	52
RCR3	Coldwater River, to Duck Creek	130
RCR4	Coldwater River, to Montcalm Road	296
RCR5	Coldwater River, to Messer Brook	See Table A5
RCR5trib	Messer Brook, to Coldwater River	351
RCR6	Coldwater River (Little Thornapple River), to Lower Lake tributary	633
RCR7	Coldwater River (Little Thornapple River), to unnamed tributary	451
RDC1	Duck Creek, to Coldwater River	210
RDC2	Duck Creek, to Montcalm Road	769
RDC3	Duck Creek, to Nash Highway	746
RPLC1	Pratt Lake Creek, to Bear Creek	535

Table A5: Reach RCR5 Storage-Discharge Relationship

Storage (acre-feet)	Discharge (cfs)
0	0
688	54
963	193
1155	409
1265	698
1375	1055
1458	1479

Appendix B: Hydrologic Model Calibration Technical Information

Precipitation and river stage data were collected from April 12 to June 27, 2002, and released in a memo dated July 12, 2002. This memo is included as Appendix C of this report.

Storms used to calibrate a hydrologic model are most useful if they have a single intense rainfall event. The rainfall event used to calibrate the hydrologic model occurred on May 11-12, 2002. The storm total was 1.91 inches, as recorded by the rain gage in Lake Odessa, which is in the eastern portion of the watershed. The rain gage at Morrison Lake, which is north of the watershed, recorded 2.13 inches. The rain gage in the lower watershed was not functioning. The rainfall used to calibrate the model was 1.91 inches applied uniformly over the entire watershed.

The calibration data indicated that the 274-acre wetland complex between approximately Andrews and Farrel Roads is attenuating peak flows and that the lag method is therefore inadequate for this reach. The reach routing method was changed to Modified Puls, using a storage discharge relationship estimated using USGS quadrangles and our rating curve for the Coldwater River at Montcalm (East) Street. The results are shown in Figure B1.

The calibration data also indicated that the model was simulating a longer than observed travel time for flows from the three upper watershed monitoring locations to the lower watershed location, Coldwater River at Morse Lake Road. This may be due to wave celerity, which means that the flood wave advances faster than the water velocity. The lag values of the lower stream reaches were adjusted so that the timing of the peak flows better match the calibration data. The adjustments are shown in Table B1. The results are shown in Figures B2 to B4.

Table B1: Flood wave celerity adjustments

Reach	Calculated Lag (minutes)	Celerity adjustment	Modified Lag (minutes)
RBC1	72	0.60	43
RCR1	860	0.50	420
RCR2	619	0.50	309
RCR2b	52	0.60	31
RCR3	130	0.60	78
RDC1	210	0.60	126
RDC2	769	0.76	589

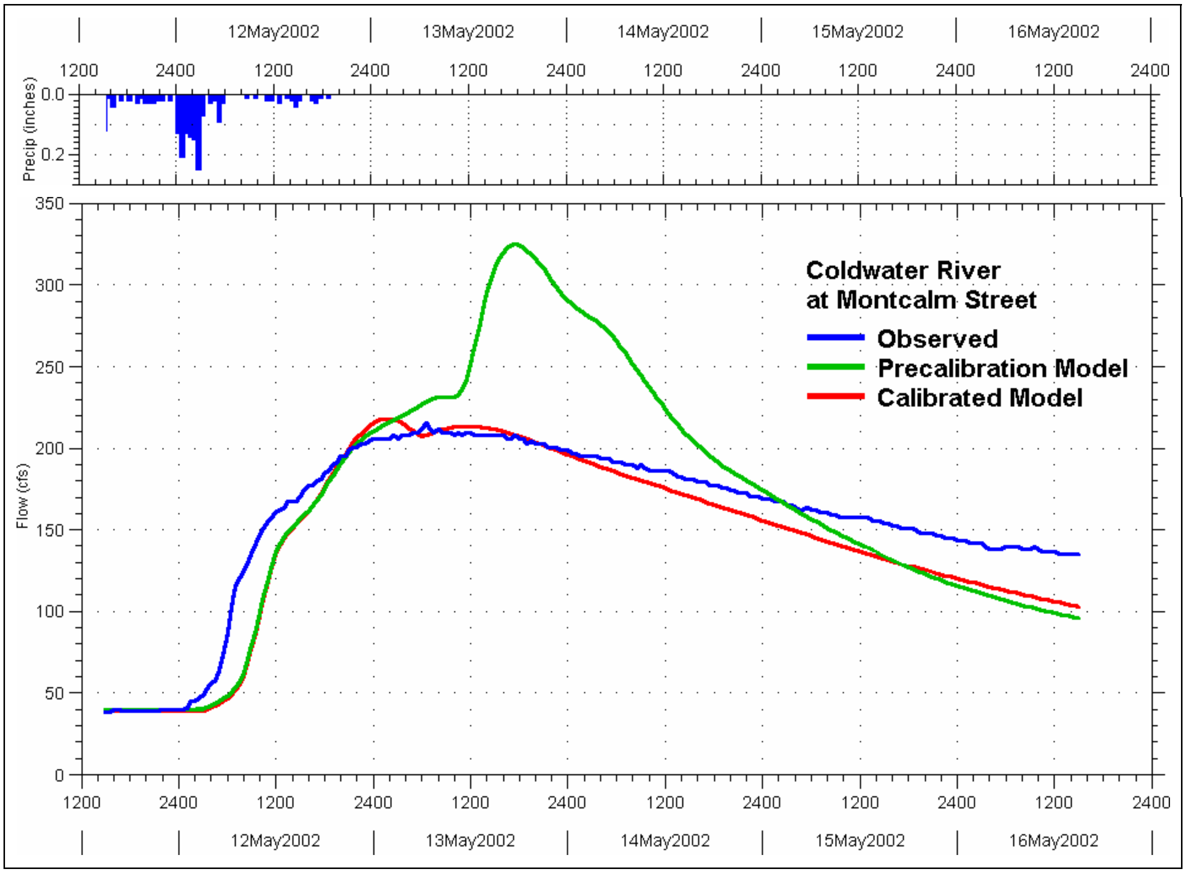


Figure B1: Coldwater River at Montcalm (East) Street, May 11-16, 2002 data

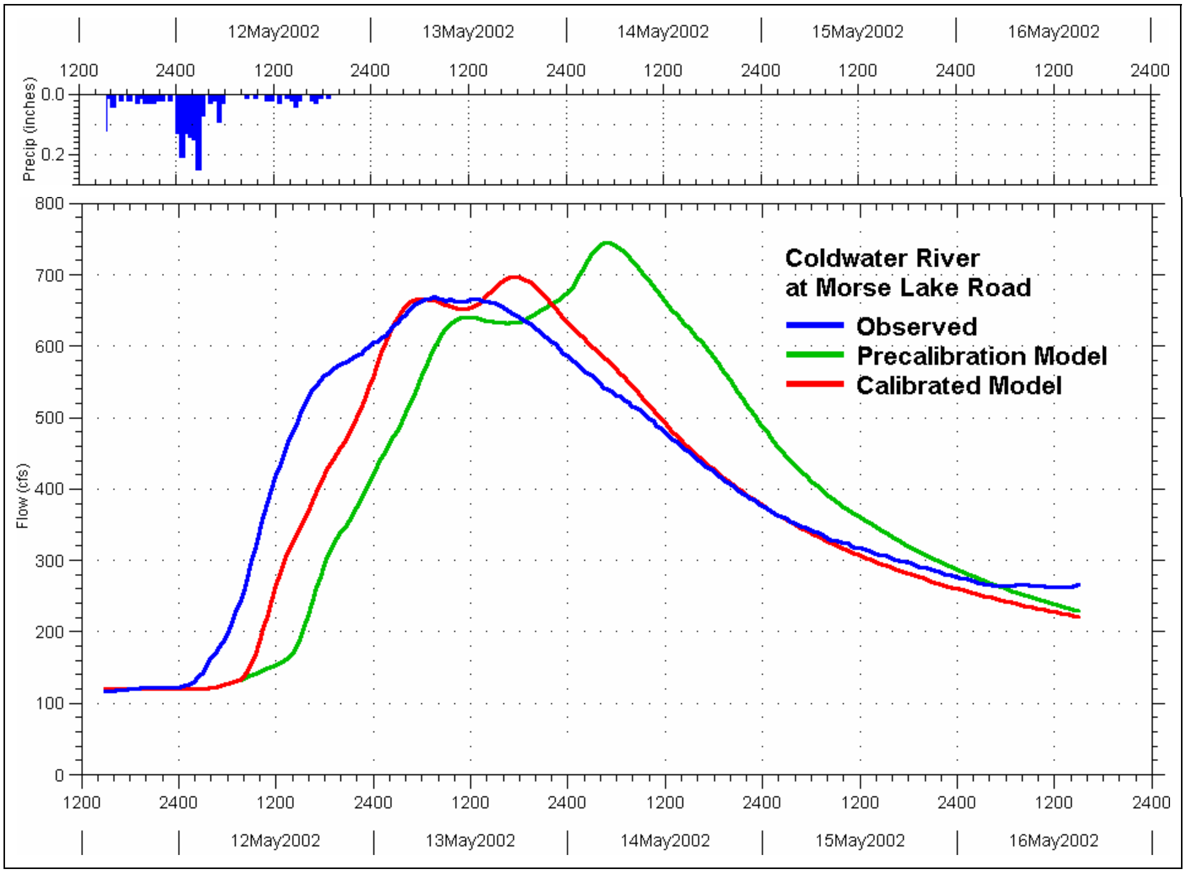


Figure B2: Coldwater River at Morse Lake Road, May 11-16, 2002 data

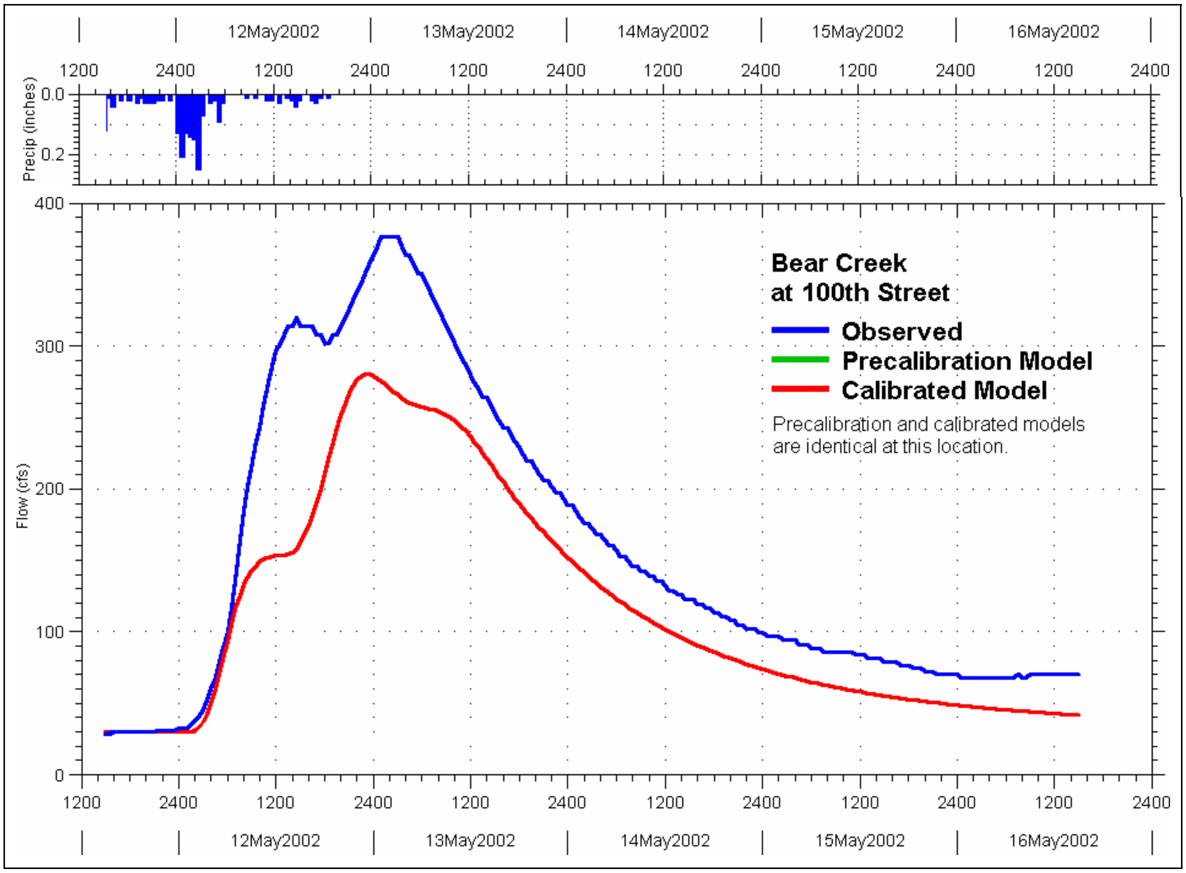


Figure B3: Bear Creek at 100th Street, May 11-16, 2002 data

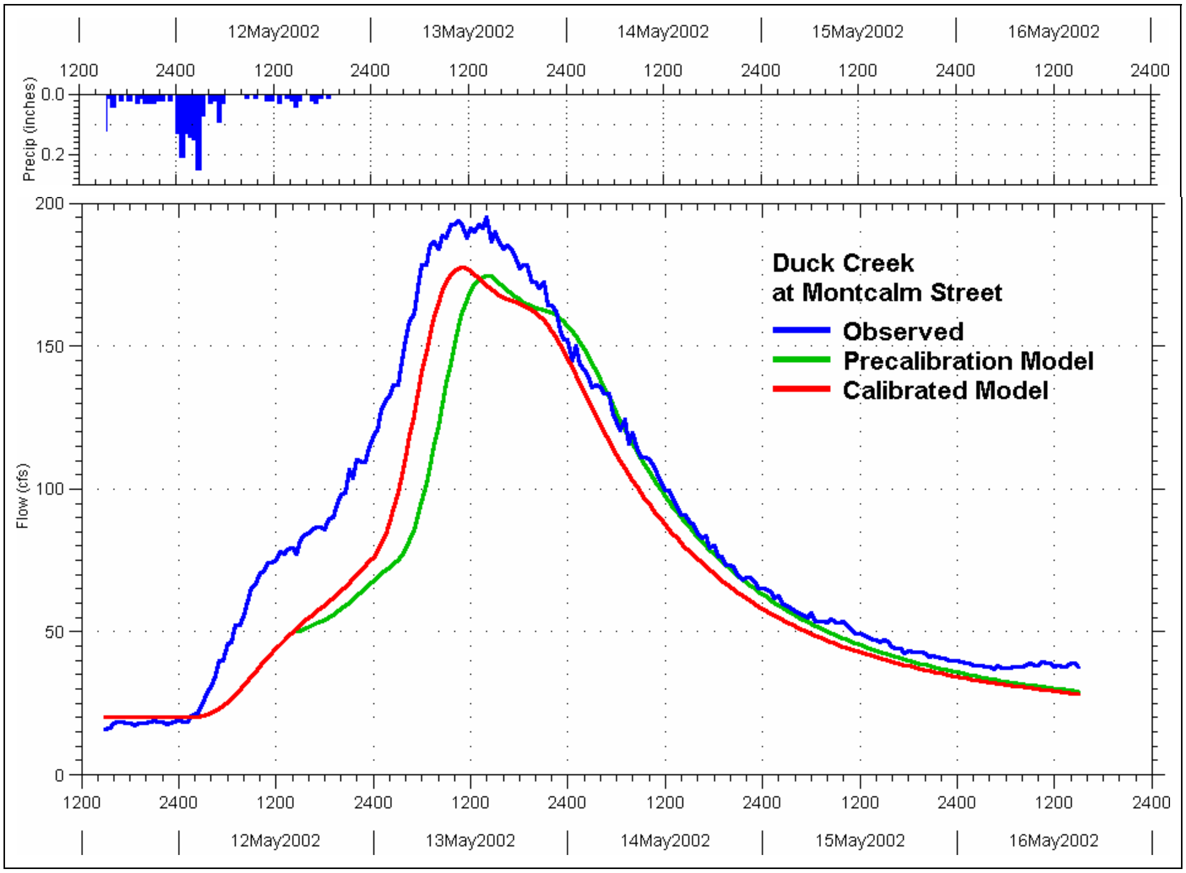


Figure B4: Duck Creek at Montcalm Street, May 11-16, 2002 data

Appendix C: Flow Monitoring Calibration Data

STATE OF MICHIGAN
DEPARTMENT OF ENVIRONMENTAL QUALITY
LANSING

JOHN ENGLER
GOVERNOR

RUSSELL J. HARDING
DIRECTOR

September 6, 2002

TO: Janice Tompkins, Nonpoint Source Unit
Surface Water Quality Division, Grand Rapids District Office

FROM: Dave Fongers, Hydrologic Studies Unit
Land and Water Management Division

SUBJECT: Coldwater River Flow Monitoring

As requested, the Hydrologic Studies Unit (HSU) of the Land and Water Management Division (LWMD) has completed its monitoring study of the Coldwater River. This analysis was requested in support of a Section 319 grant. Nothing in this report is an authorization to do any work within the watershed that would require a permit or guarantees that work proposed based on this report will be permitted or funded.

Precipitation and river stage data were collected from April 12 to June 27, 2002, and released in a memo dated July 12, 2002. This report provides the calculated flows based on the stage data. The monitoring locations are shown in Figure 1. Figure 2 is a graph of all of the precipitation and river stage monitoring data. Figure 3 shows the flows calculated from the stage data in Figure 2. The technique used to convert the stage data to flows in discussed in Appendix A.

The monitoring data are intended to be used to calibrate a hydrologic model. Figures 4 and 5 show the precipitation, stage, and flow information for the subset of the monitoring data that would be most useful for this purpose. During this period, 2 inches of rain fell in 24 hours. This rain event has an expected average recurrence interval of approximately one year.

The monitoring data also provide information on the timing of peak flows from Tyler Creek, Duck Creek, and the upper watershed of the main stem of the Coldwater River, all of which come together near Freeport. The monitoring shows that the flows from Tyler Creek, Duck Creek, and the upper Coldwater River watershed do not peak at the same time. The peak flow from Duck Creek is significantly delayed compared to the others. Flow from upper watershed of the main stem of the Coldwater River remains high the longest, which is most likely related to the larger size of the watershed. Tyler Creek responds most rapidly to a storm event, but efforts to delay this response are not likely to reduce the peak flow in the Coldwater River, and could even slightly increase it.

If you have any questions or comments regarding our evaluation, please contact me at 517-373-0210. Digital files of the flows, precipitation, and stage data are also available on request.

Attachment

cc: Ralph Reznick, SWQD
Ric Sorrell, LWMD
Abigail Matzke, Roger B. Annis Water Resources Institute, Lake Michigan Center, 740 W. Shoreline Drive, Muskegon, MI 49441
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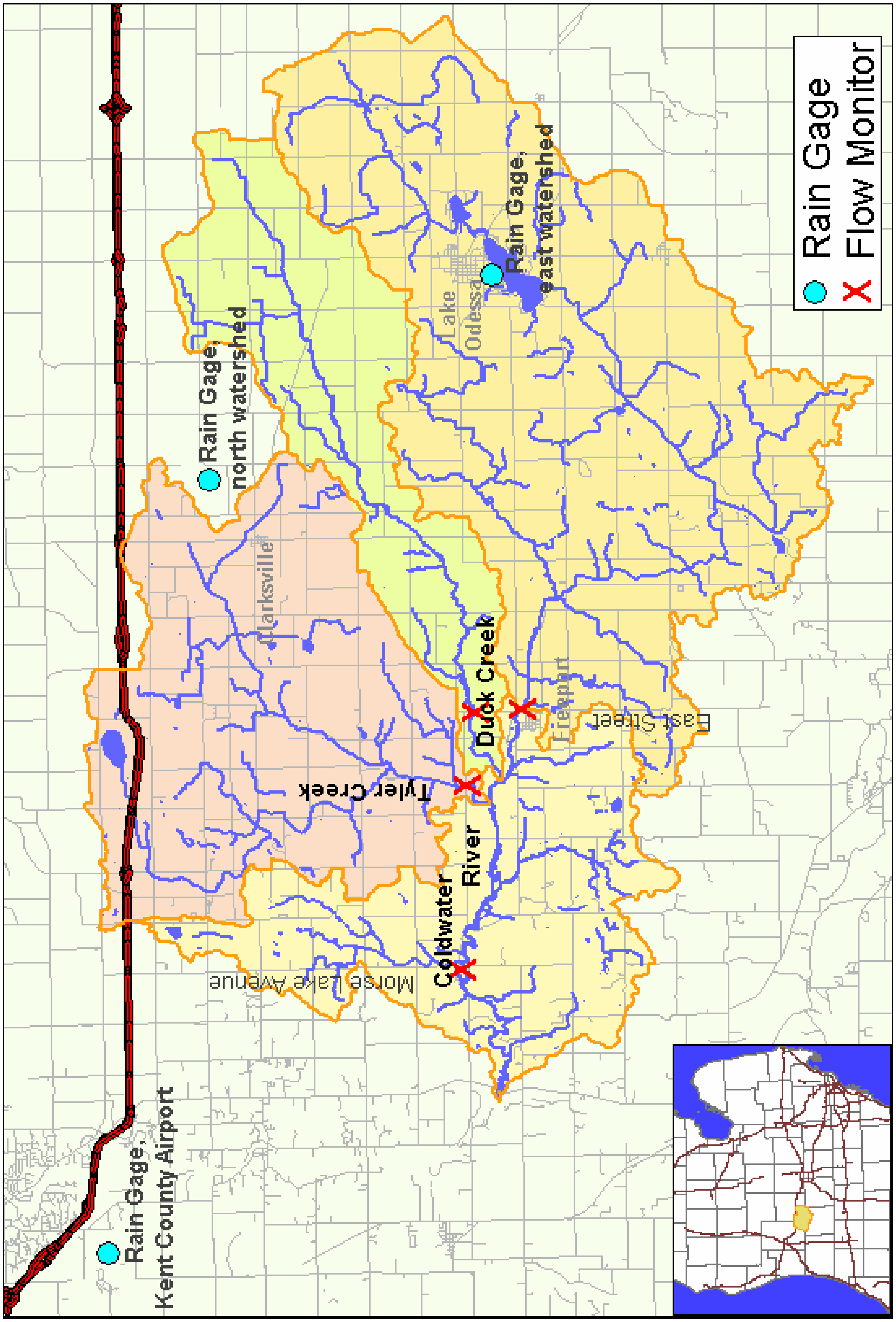

Figure 1: Watershed Monitoring Locations

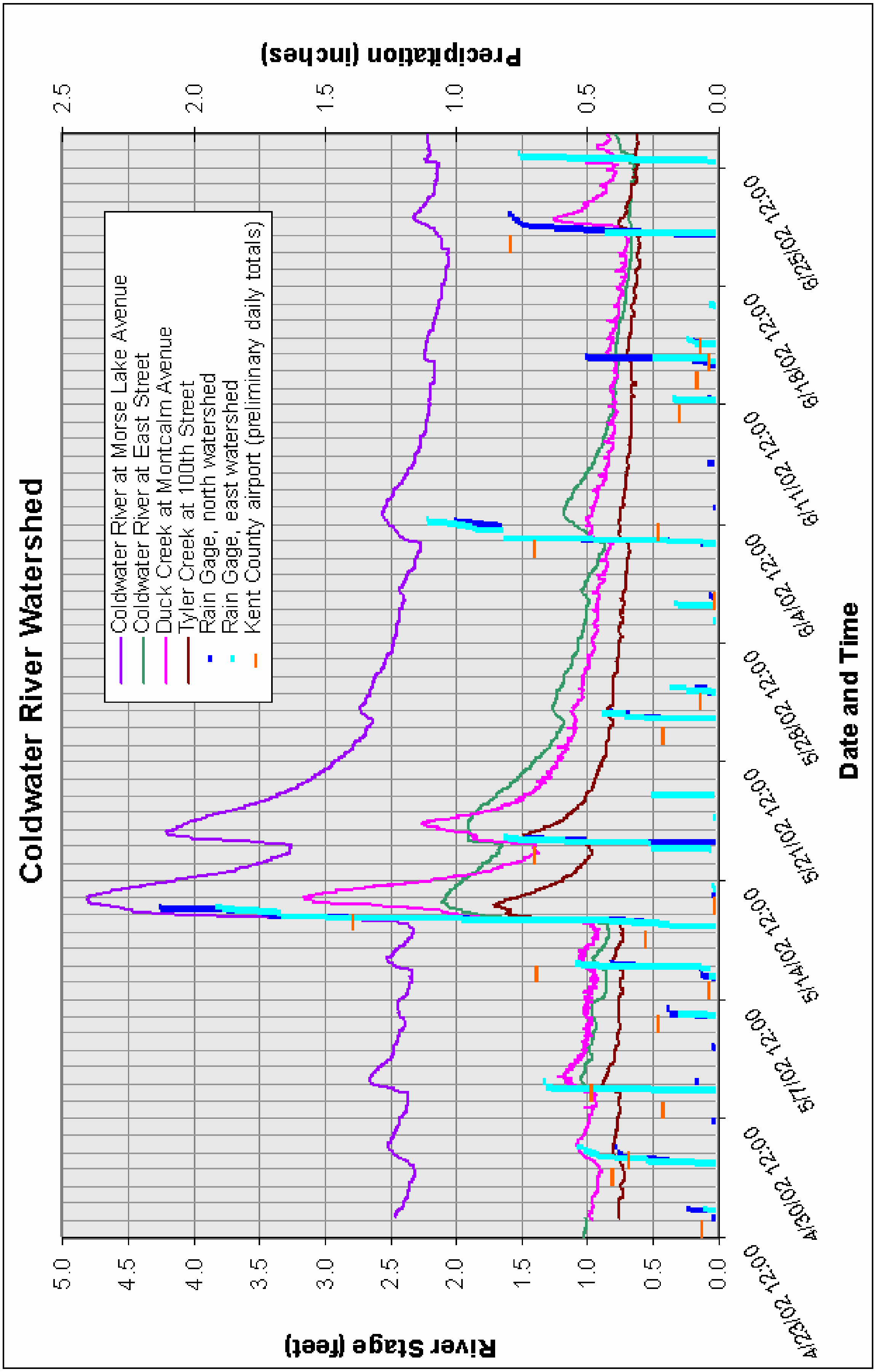

Figure 2: Coldwater River Monitoring Data

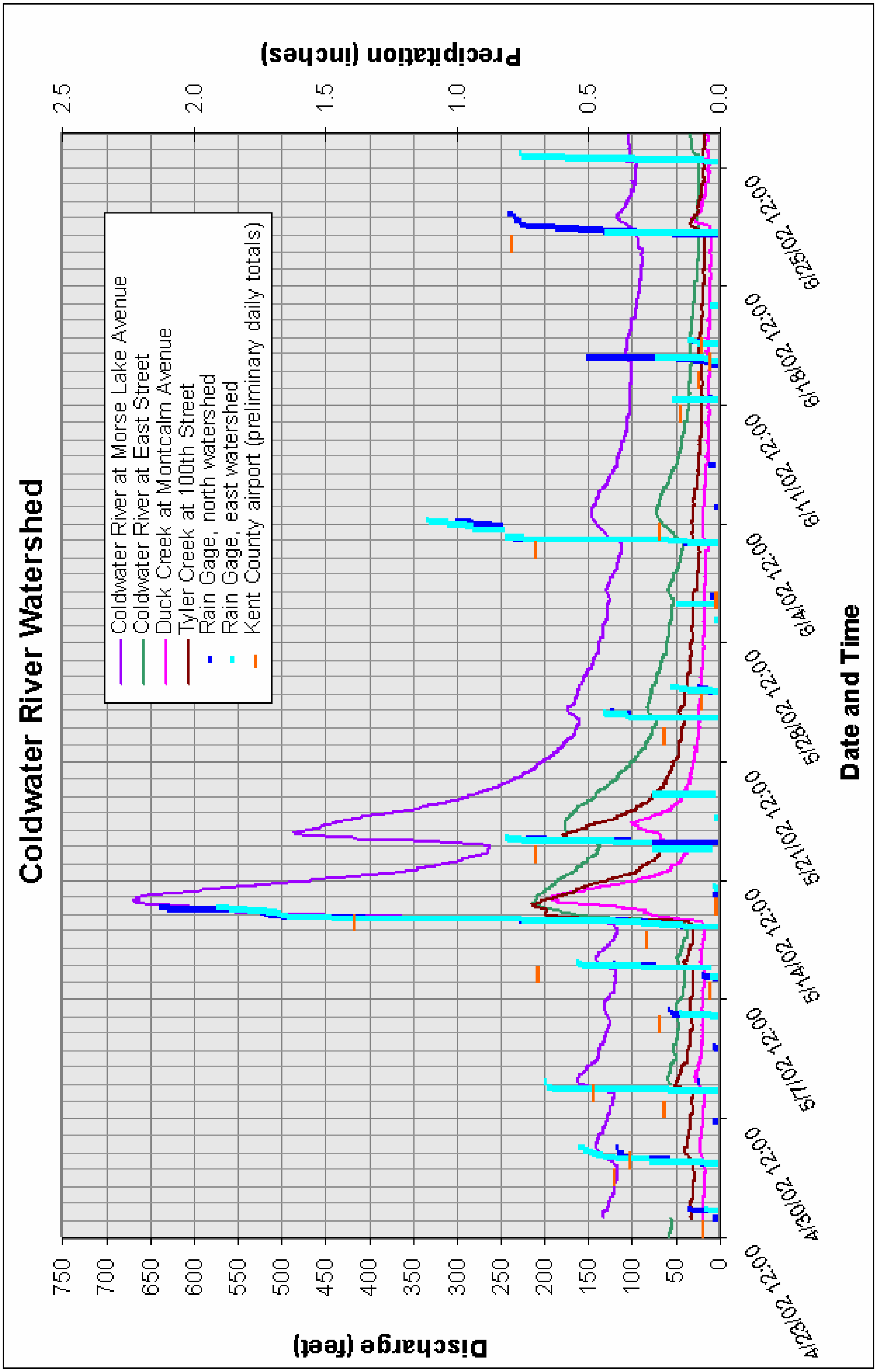

Figure 3: Coldwater River Calculated Flows

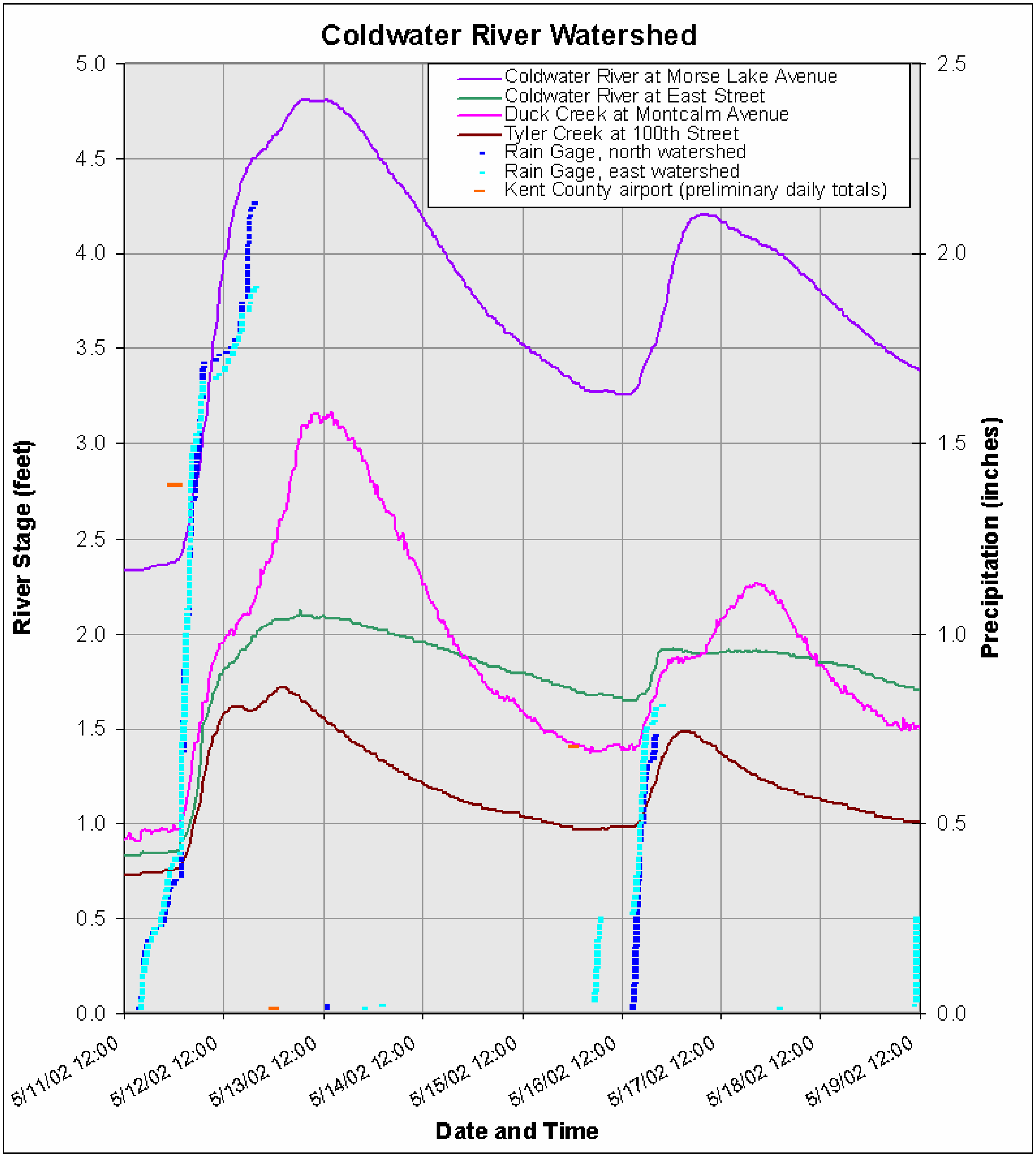

Figure 4: Selected Coldwater River Monitoring Data

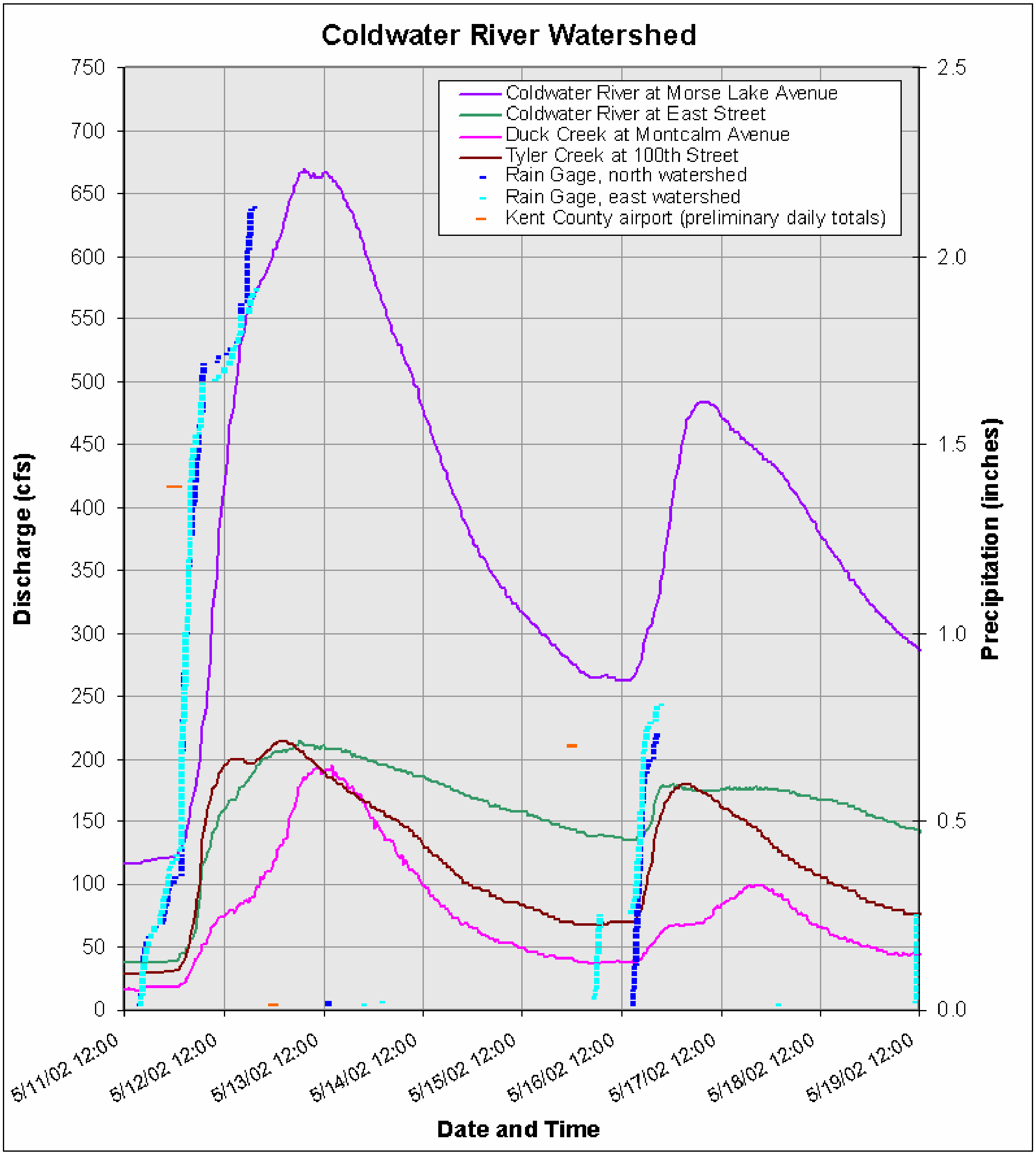

Figure 5: Selected Coldwater River Calculated Flows

Appendix A

Calculation of Flows from Stage Data for the Coldwater River Watershed

To convert the stage data to flows, a stage-discharge relationship, or discharge rating curve, was developed for each site based on the techniques described in the United States Geological Survey's Techniques for Water-Resources Investigations, Book 3, Chapter A10, 1984.

The stage that would occur at a gage if the discharge were extremely small is the gage height of zero flow (GZF). It is also defined as the point of zero flow, the highest point on the thalweg (the longitudinal thread of the stream that follows the deepest point in each cross section) downstream from the gage. Because a gage is rarely placed at exactly this elevation, the stage data were adjusted to our best estimate of this datum.

These discharge rating curves use flow measurements obtained by the HSU in accordance with MDEQ LWMD Operating Procedure Admin-99-07. All discharge measurements were included in the analysis. Development of the discharge rating curves also used a technique termed curve shaping which extends the curve beyond the measured flows based on the channel's physical characteristics. Surveys of channel cross-sections were obtained by HSU and input into HEC-RAS hydraulic models for this purpose.

A discharge rating is often a compound curve consisting of three segments: one each for the low-, medium-, and high-water (or overbank) ranges. The segments of a compound curve may be connected by short transition curves. Wide flood plains usually cause the rating to break sharply to the right at bankfull stage, and the transition from section to channel control usually causes the curve to break upward. These breaks are readily apparent when the stage data are plotted logarithmically. All of the discharge rating curves were plotted logarithmically for this purpose.

Figures 1 through 4 represent the rating curves plotted logarithmically. The upper limit of the rating curve is constrained by the survey data. That portion of the rating curve that corresponds to the river stage data recorded during the study is highlighted. Only one location, Tyler Creek at 100th Street, has a compound rating curve. Separate equations were defined for each segment of the curve. Figures 5 through 8 depict the final rating curves.

As an indicator of the accuracy of the rating curves, the flows calculated for the Coldwater River at East Street, Tyler Creek at 100th Street, and Duck Creek at Montcalm Avenue were summed and compared to the flow calculated for the Coldwater River at Morse Lake Avenue. Since the tributary flows represent 86 percent of the drainage area of the Coldwater River at Morse Lake Avenue, that flow is scaled by 86 percent for the comparison shown in Figure 9.

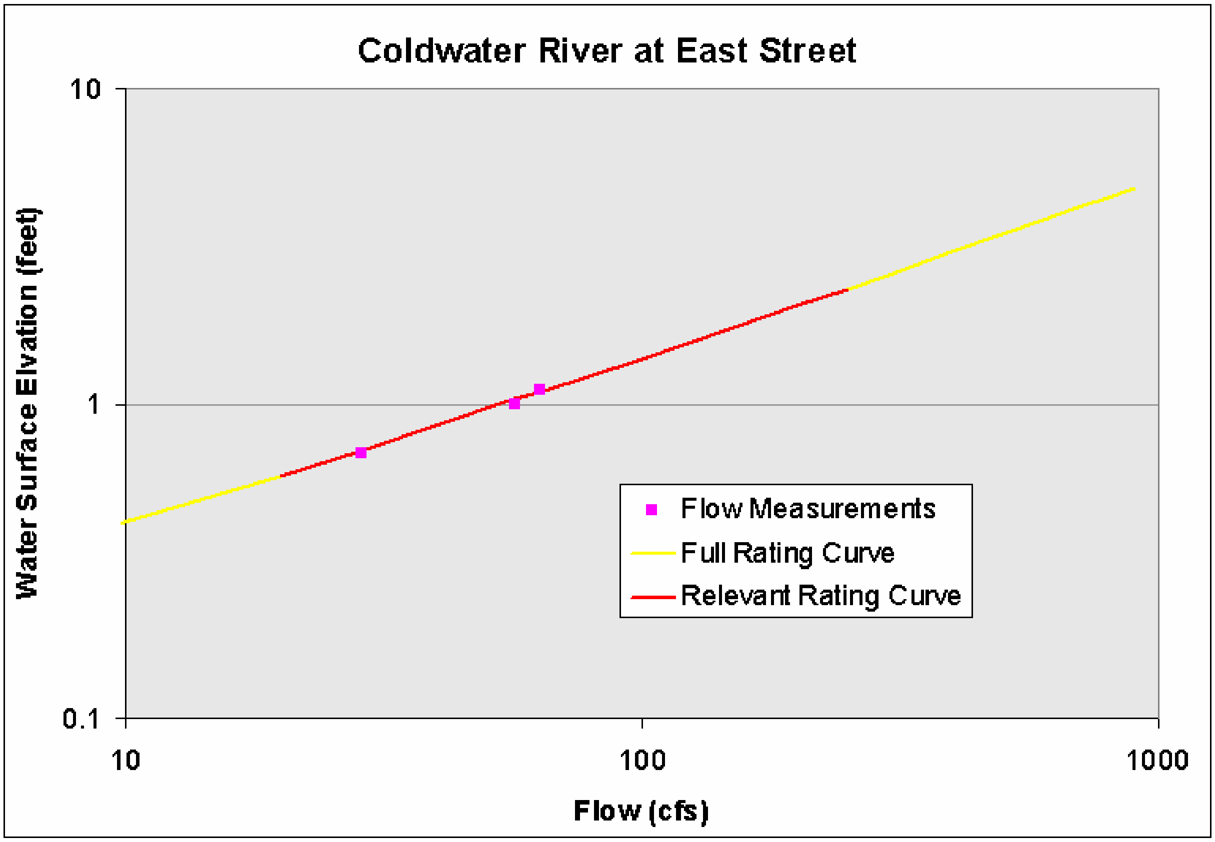

Figure 1: Rating Curve, Coldwater River at East Street, Logarithmic Plot

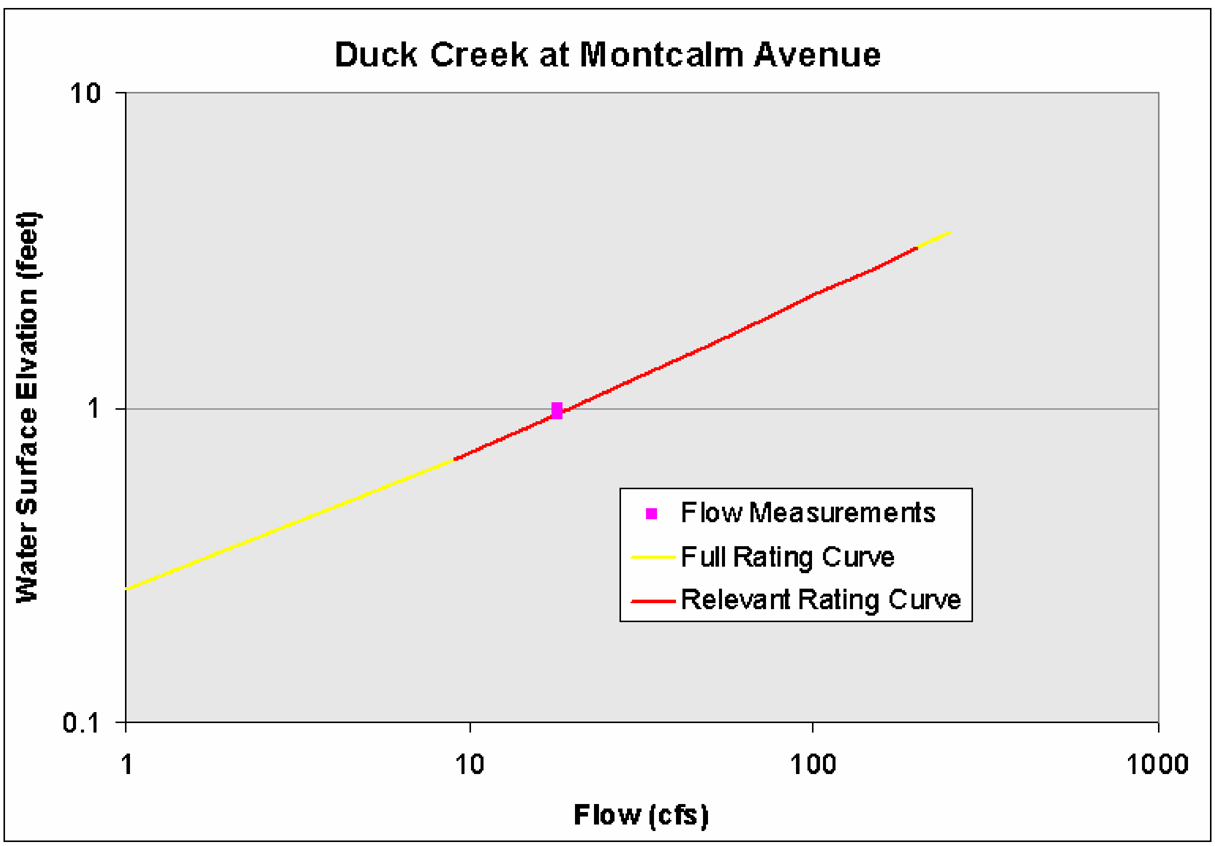

Figure 2: Rating Curve, Duck Creek at Montcalm Avenue, Logarithmic Plot

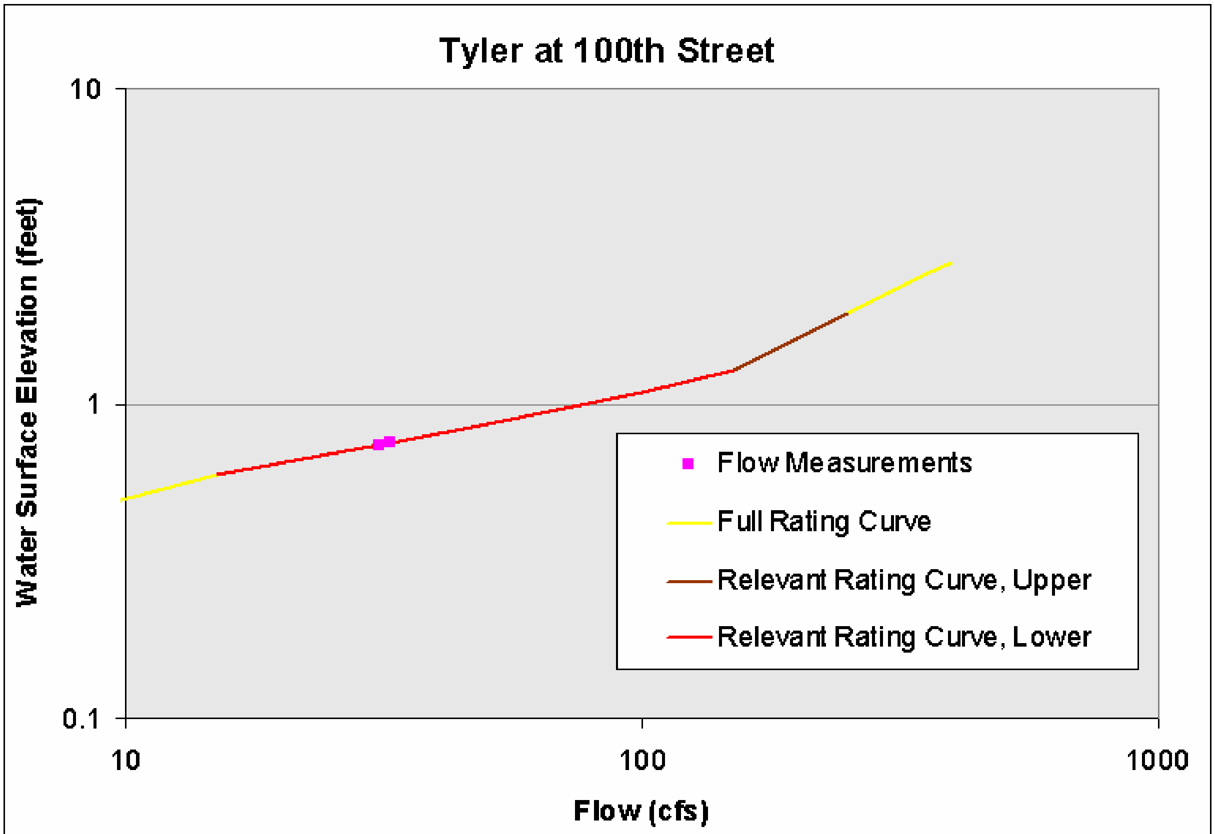

Figure 3: Rating Curve, Tyler Creek at 100th Street, Logarithmic Plot

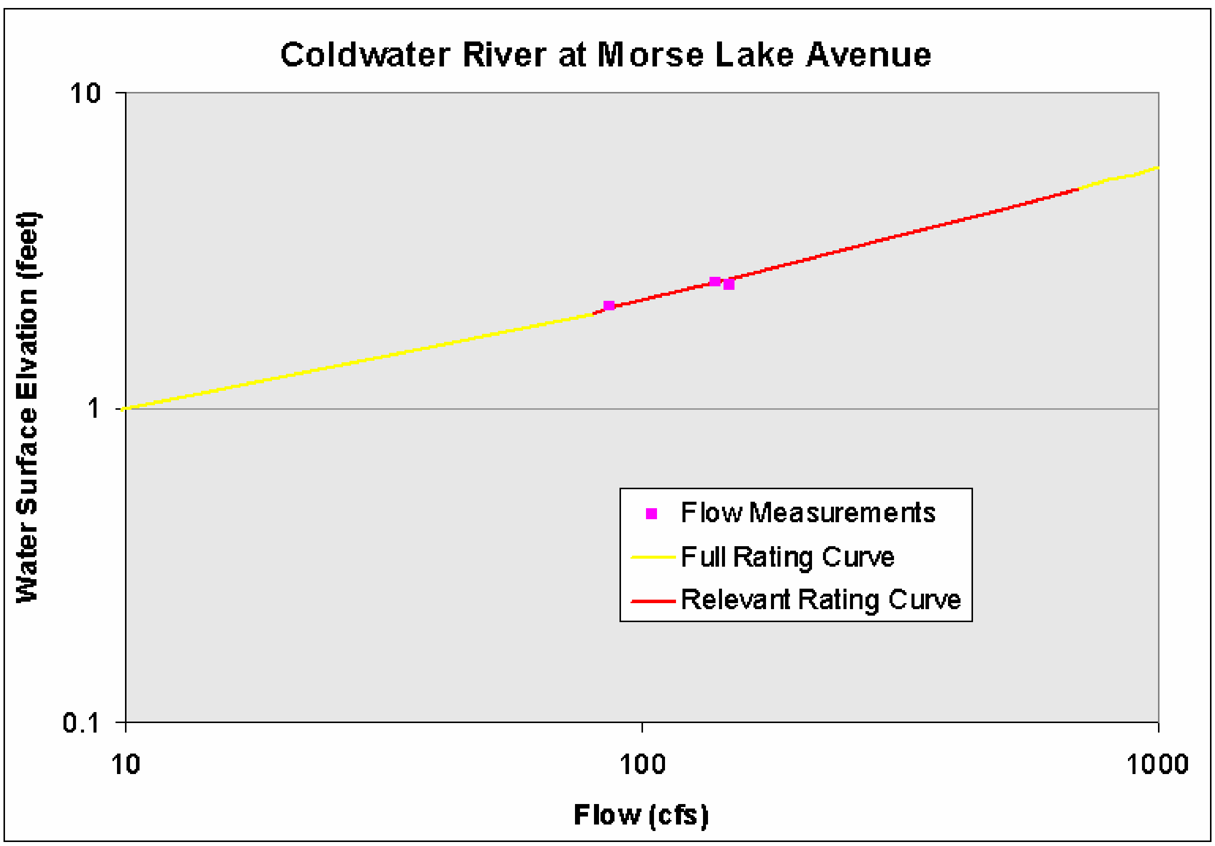

Figure 4: Rating Curve, Coldwater River at Morse Lake Avenue, Logarithmic Plot

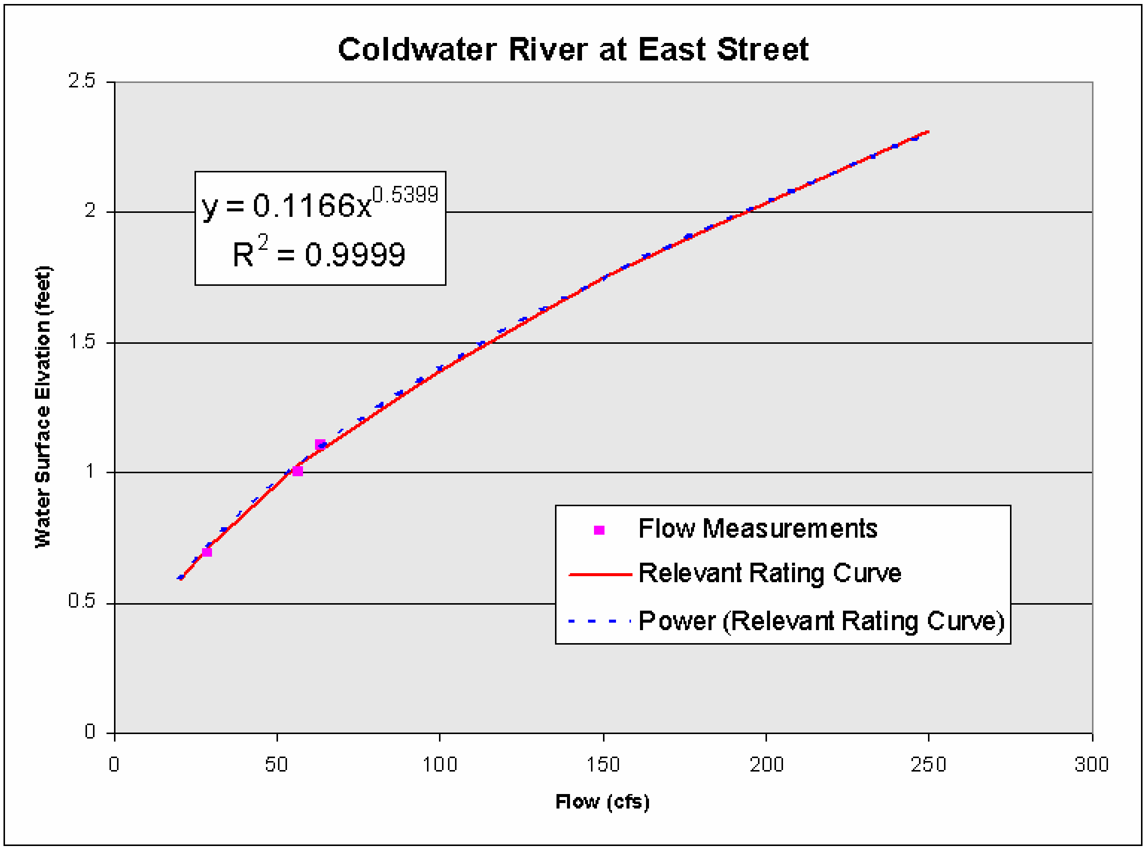

Figure 5: Final Rating Curve, Coldwater River at East Street

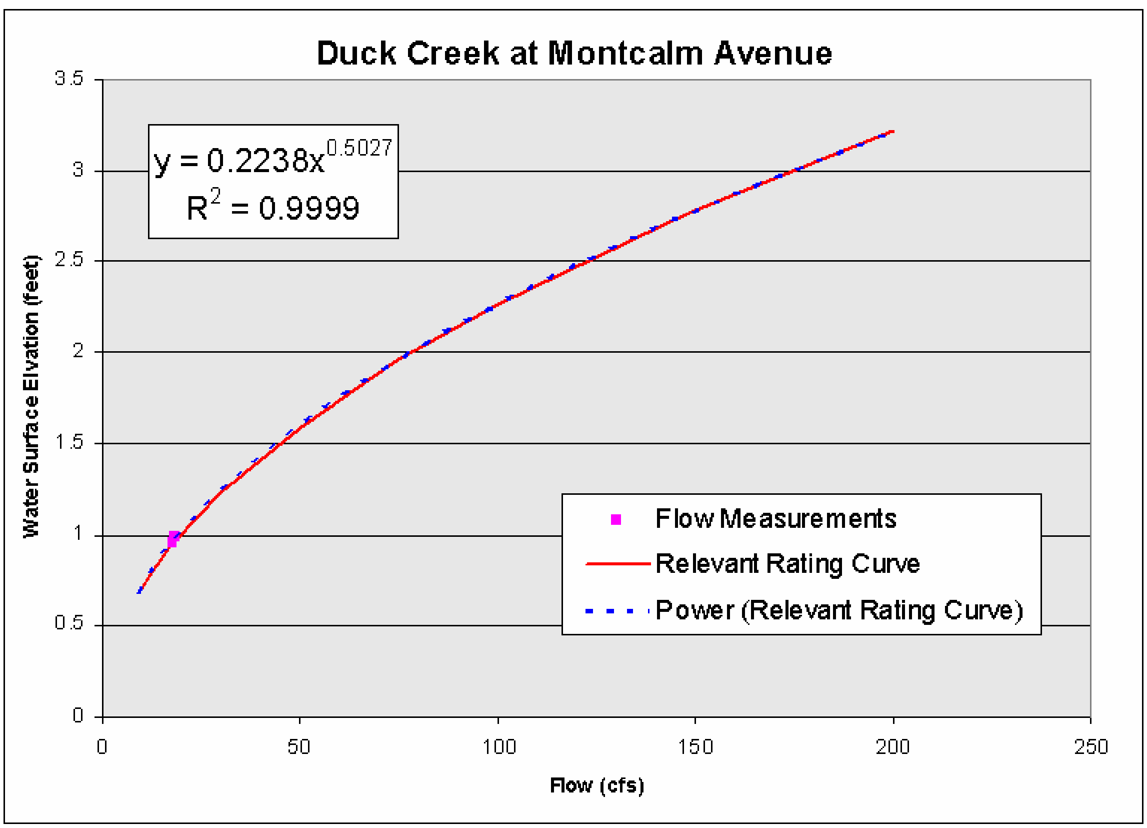

Figure 6: Final Rating Curve, Duck Creek at Montcalm Avenue

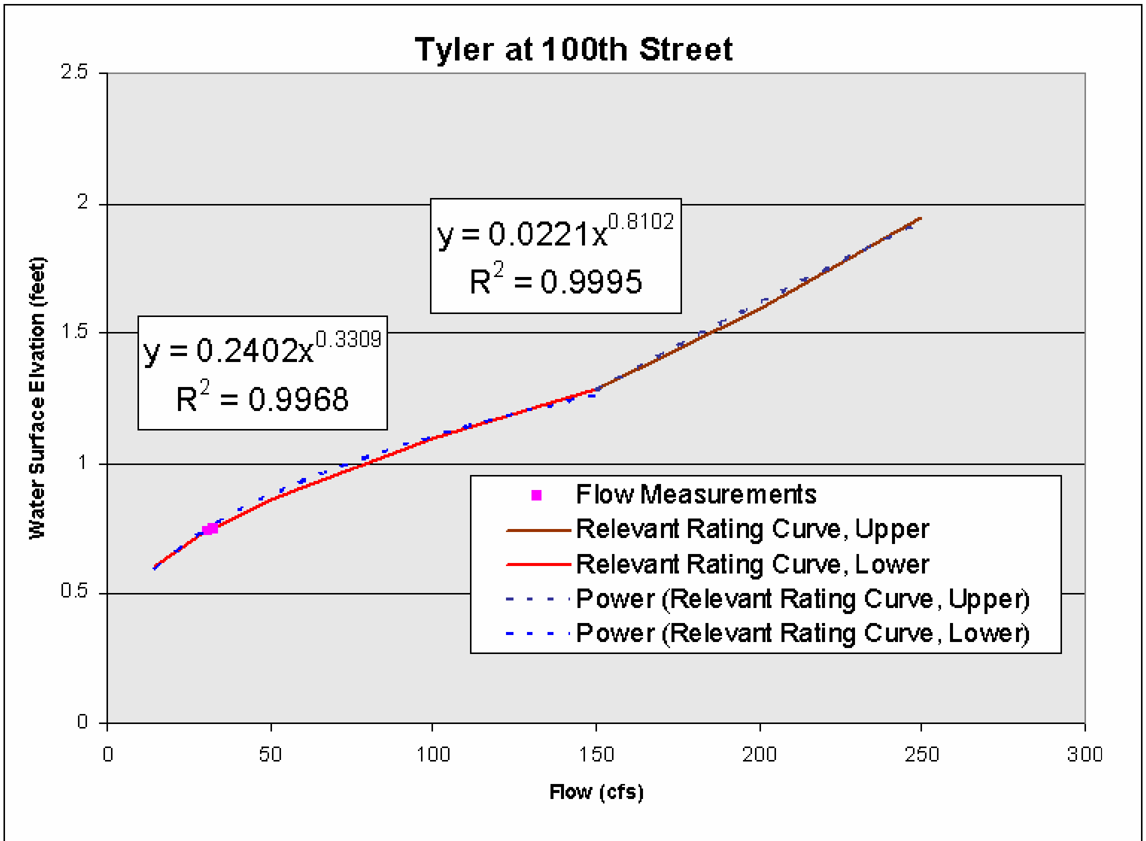

Figure 7: Final Rating Curve, Tyler Creek at 100th Street

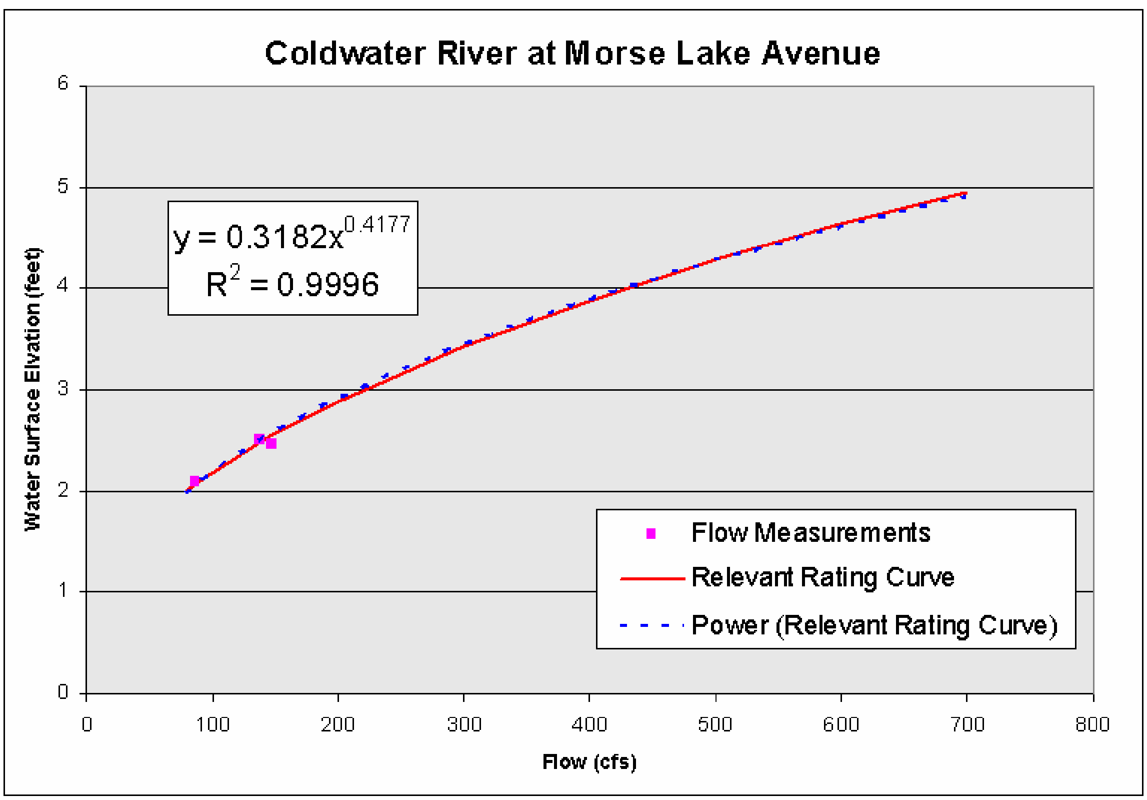

Figure 8: Final Rating Curve, Coldwater River at Morse Lake Avenue

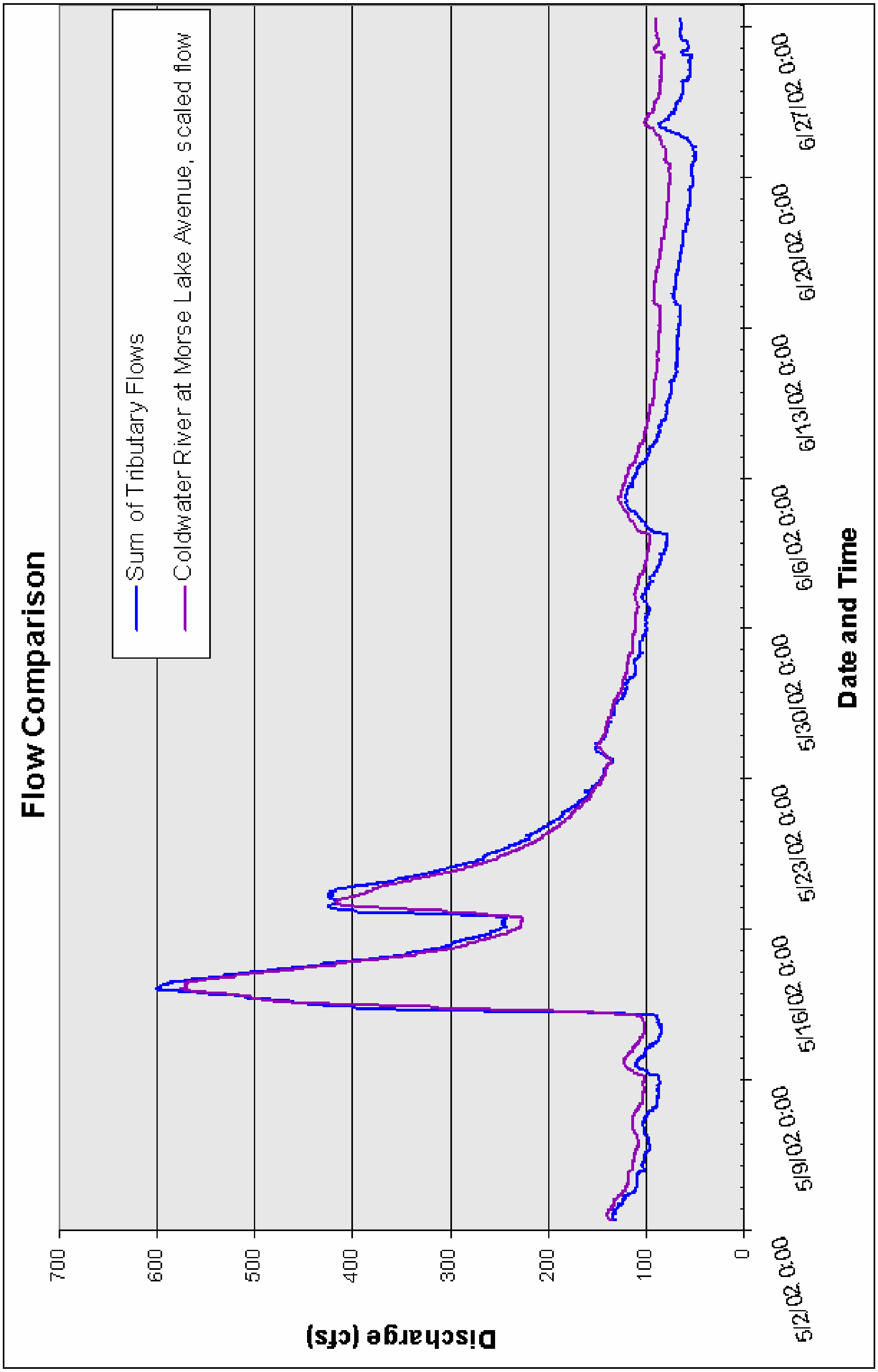

Figure 9: Comparison of 86 percent of the Coldwater River flow at Morse Lake Avenue to the sum of the Coldwater River at East Street, Duck Creek, and Tyler Creek flows